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Faster than light

Neutrino mystery latest

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Welcome

April 2012

SUBSCRIBE AND **SAVE 30%** p32

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The last time anybody visited the deepest part of the world's oceans was over 50 years ago. When you consider it's nearly 11km straight down, that's hardly surprising. In recent decades, there hasn't been a submersible capable of matching that feat. But now five teams are having a crack at the ultimate deep-sea challenge, and it's not only for the glory. As well as financial rewards, there are minerals and a potentially valuable scientific bounty that could change our lives. Dive in on page 34.

It was also 50 years ago that the first British-designed satellite was launched. Today, Britain is a world leader in the design and construction of satellites for communications and scientific research. But how do today's satellites differ from those early models? See page 48 to find out.

There's another incredible story on page 77, where we look at an experiment that shocked the world last year. Could particles called neutrinos really have travelled faster than light? Has a crack appeared in Einstein's theory after all these years? Now that the dust has settled, we talk to the Italian scientists who worked on the experiment to find out if this seemingly unbelievable result could be true.

Elsewhere, there's a distinctly spring-like feel to the issue. To celebrate the season of newborn lambs and Easter bunnies, our features editor JV Chamary looks at what makes things cute, and how our penchant for them can be exploited for commerce. And in readiness for the inevitable April showers, we subjected four raincoats to a veritable deluge. Did their water-resistant capabilities live up to the claims? Find out on page 100.

Even if you're well equipped, going out in the pouring rain takes a certain amount of willpower. But what is it that defines mental toughness, and how can you build more of it? Scientists have been searching for answers recently, and what they found may surprise you. Turn to page 61 for more.

Until next issue,

Graham

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Unravelling the FABRIC of the UNIVERSE
Robert Matthews investigates how the structure of space could shed light on black holes, the Big Bang and the nature of reality itself

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- **Watch the first self-guided bullet**
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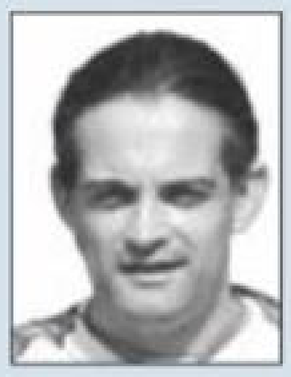
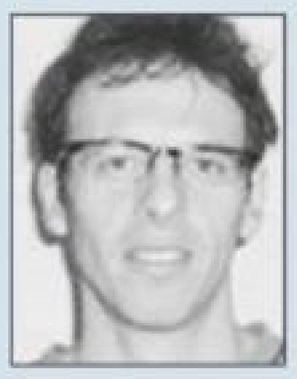
What I've found out this month

- In future, computers could speak what's on your mind (p20)
- This year's *Search For A Scientist* will compare voices to faces (p44)
- Dogs have willpower issues too… (p65)

Experts



Edwin Cartlidge
Edwin is a science journalist based in Rome, and a former news editor of *Physics World*. On p77, he investigates the extraordinary finding that neutrino particles travelled faster than light.



Nic Fleming
Nic is a freelance science and technology journalist, formerly of *The Daily Telegraph*. On p34, he talks to the teams competing – unofficially, of course – in a race to the very bottom of the ocean.

John Tierney
John is a science columnist for the *New York Times*. He co-authored the book *Willpower* with social psychologist Roy Baumeister and, on p61, describes what gives you all-important self-discipline.

Jo Tinsley
As features editor of *Countryfile* magazine, Jo knows all about keeping dry outdoors. So on p100, with the help of some hoses, we asked her to test four waterproof coats to their limits.

How to get in touch

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COVER: ILLUSTRATION BY MAGICTORCH

April 2012

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Sending people grabs headlines. Robots were on the Moon in the 1960s but we didn't hear about it.

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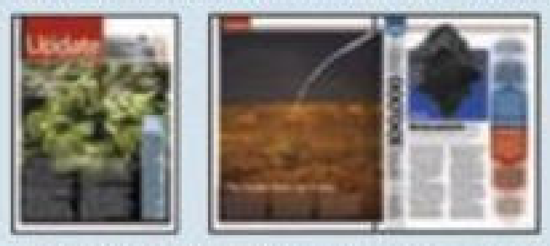

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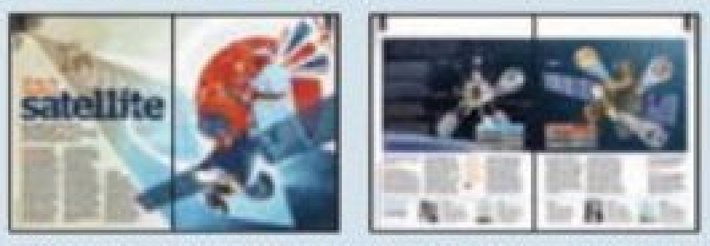

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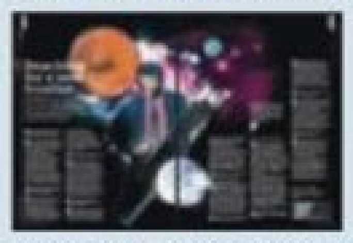

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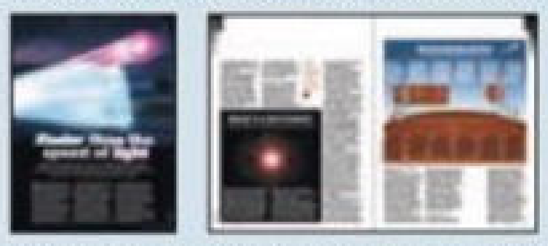

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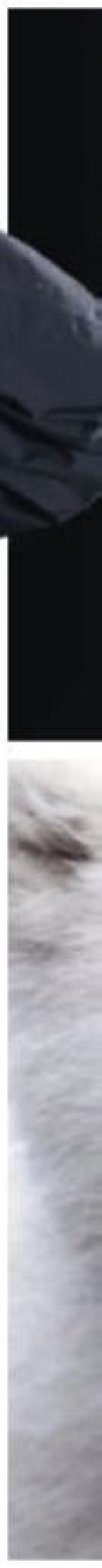

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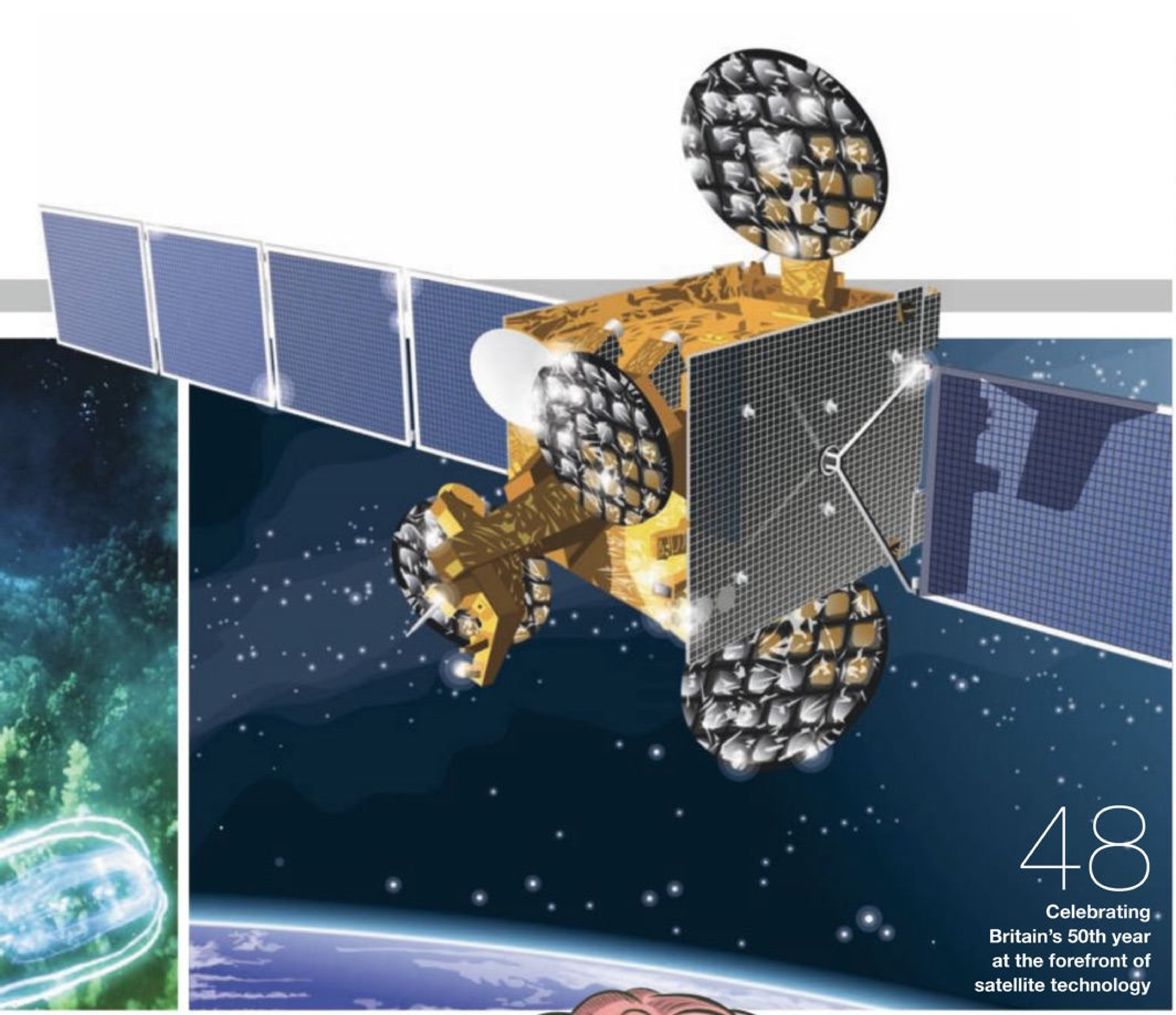

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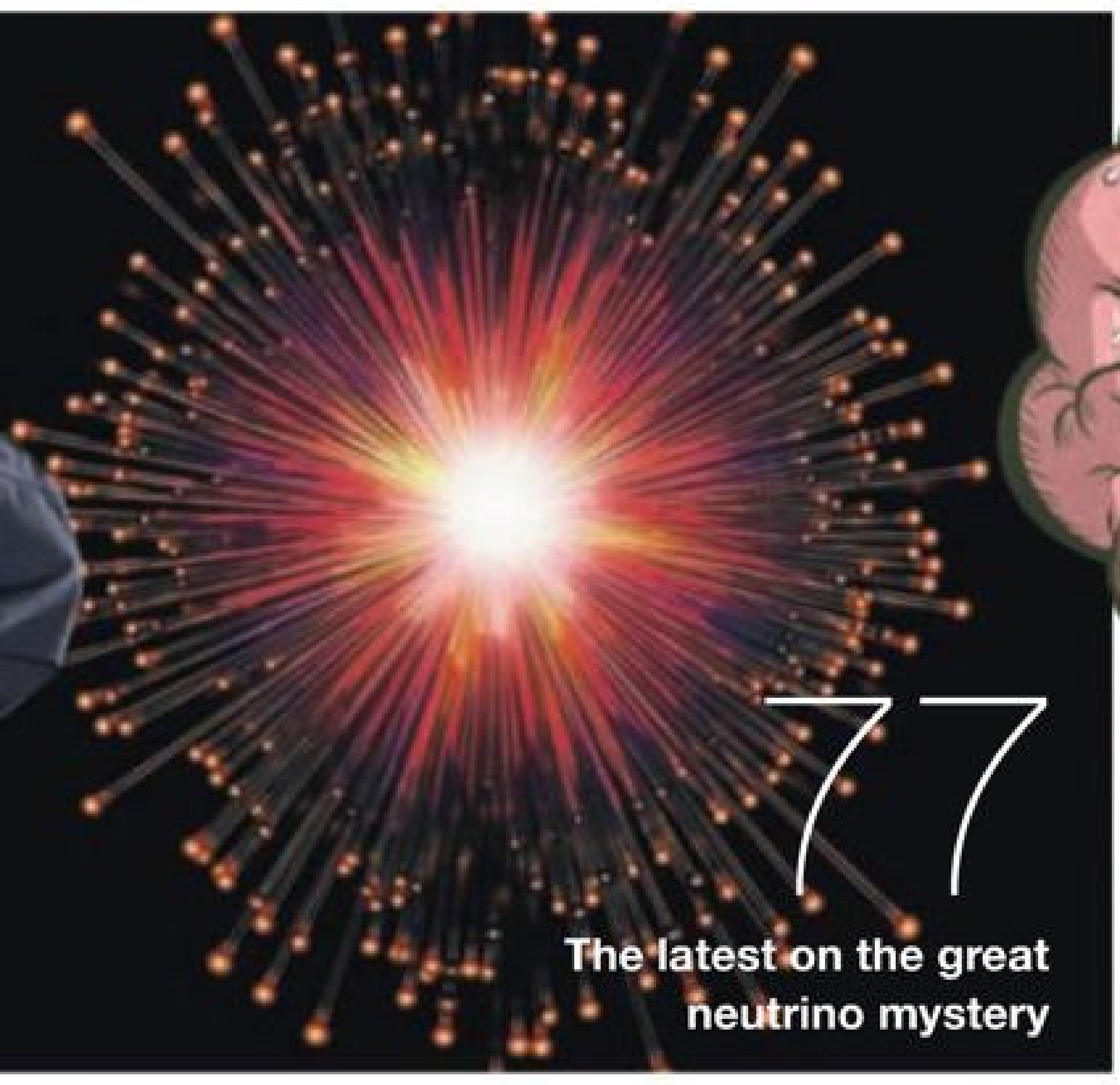

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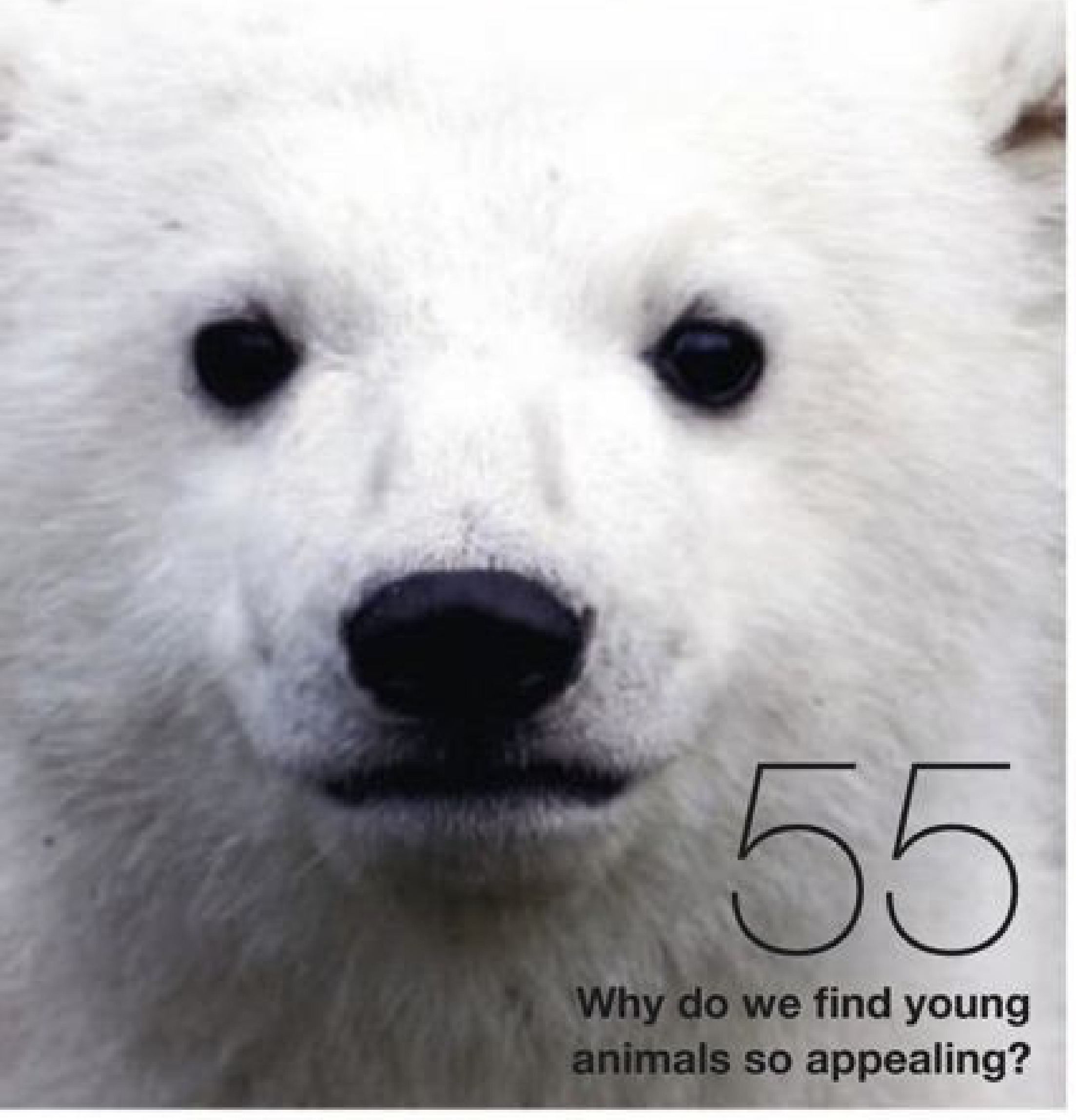

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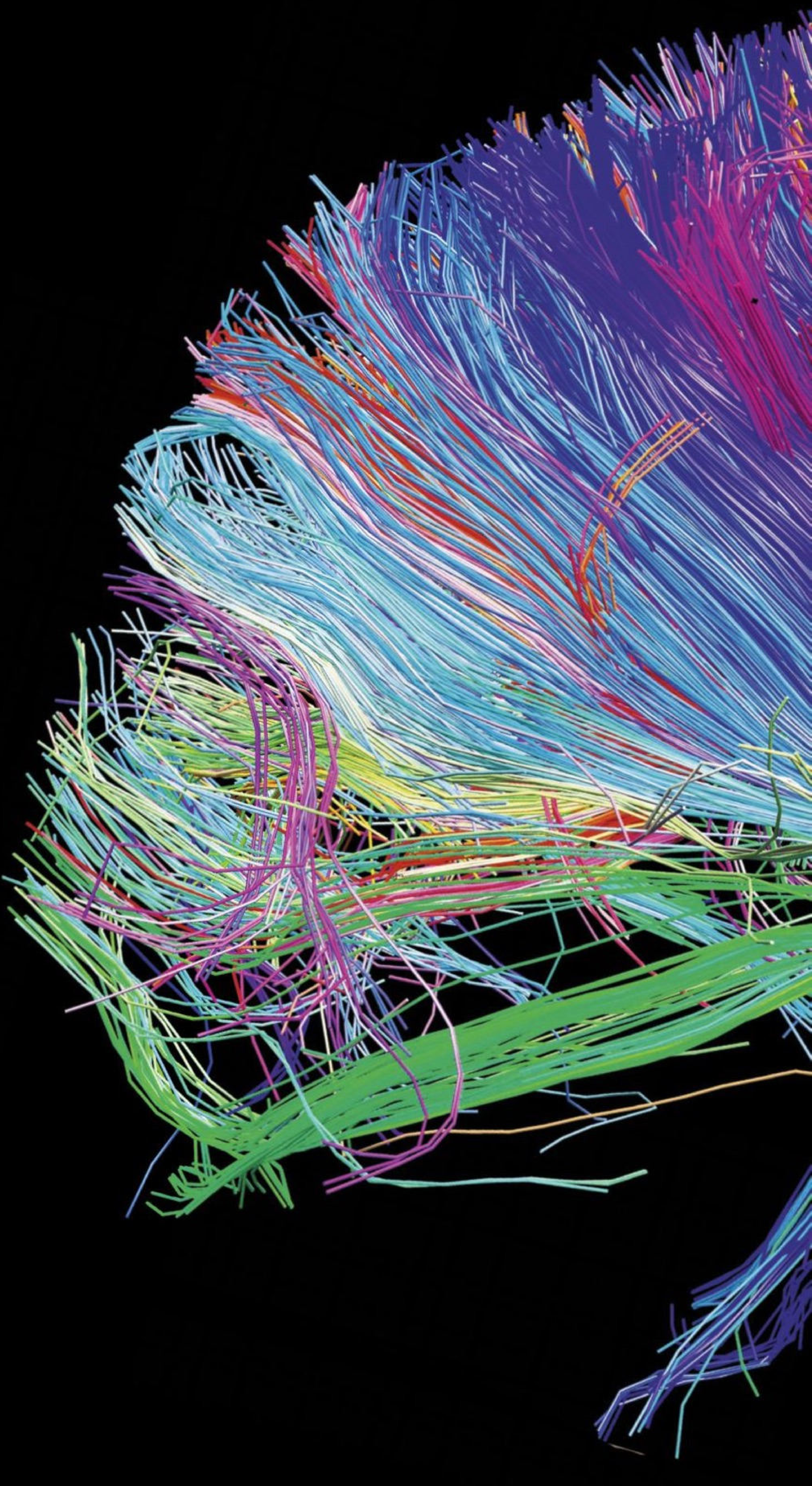
Mind map

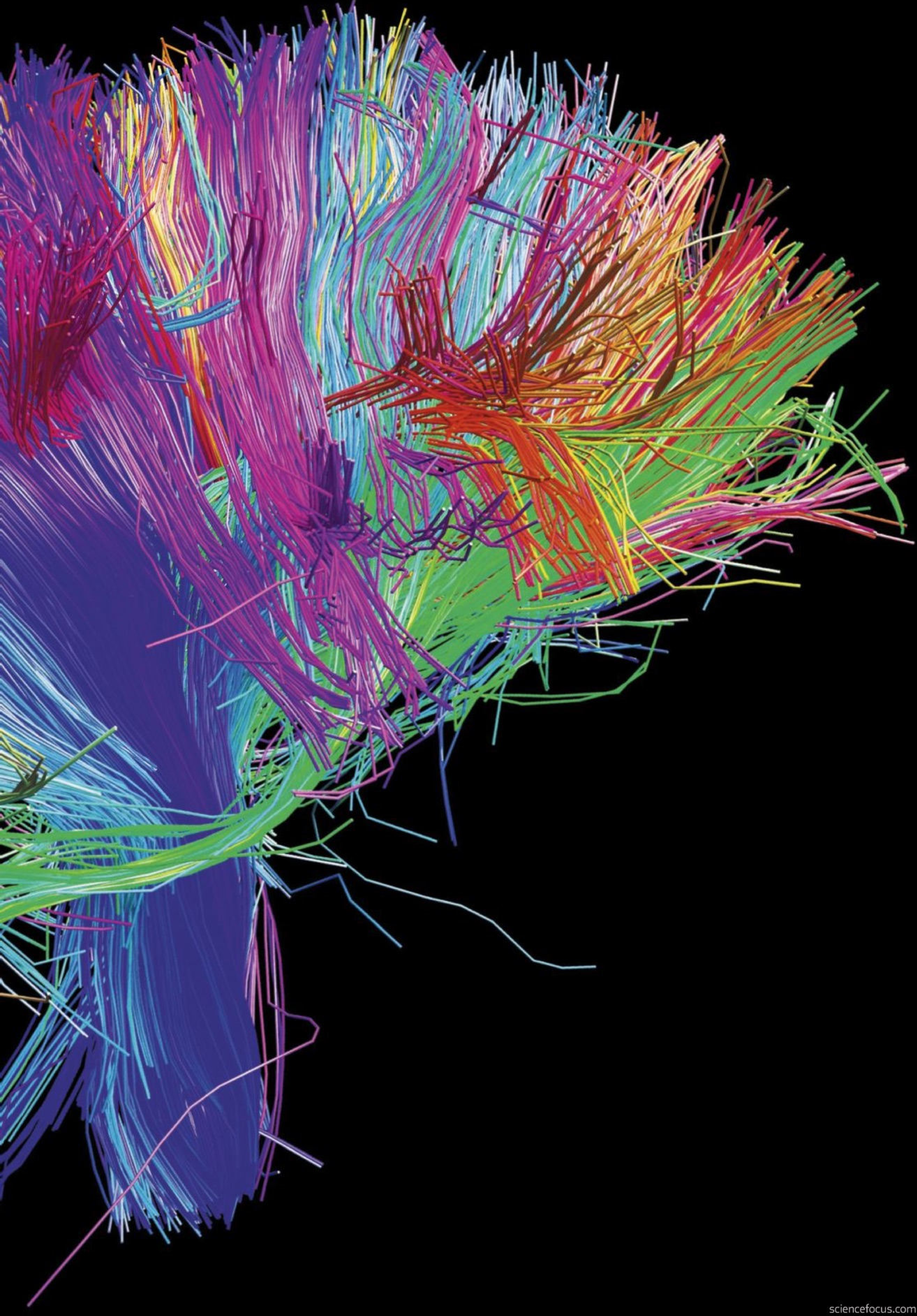
Deep inside the brain are the communication cables that link together the different regions of the most complex organ inside the body. These cables are actually long nerve cells, or neurons, that make up the 'white matter'. Their every twist and turn can be traced by using Magnetic Resonance Imaging (MRI) to follow the path of water molecules as they diffuse through a living brain.

This particular neural map has been created as part of the Human Connectome Project, a five-year effort to map all the connections inside the brain. It's a challenge that's occupying the brightest minds at US universities and Massachusetts General Hospital. "Every significant neurological disease has connectivity related to it," says Associate Professor Van Wedeen, a radiologist at Harvard Medical School.

In this picture, green strands show anterior to posterior (front to back) connections. Left to right connections are in red, while blue strands represent neurones that make their way down the brain stem into the spine.



ARTHUR TOGA/VAUGHAN GREER/LABORATORY OF NEURO IMAGING AT UCLA/RANDY BRUCKNER/BRUCE ROSEN/VAN J WEDEEN/MARTINOS CENTER FOR BIOMEDICAL IMAGING AT MGH



MIKE COE/STFC

Molecular sleuth

Inside the 'belly' of this X-ray photoelectron spectrometer, which looks uncannily like a robot, are a series of interconnected stainless steel chambers in which the chemical make-up of practically anything can be determined down to the atomic level.

An X-ray beam is fired at the surface of a material, releasing electrons. Analysing the energy of these electrons, and knowing the energy of the X-ray photons required to release them, reveals a vast amount of information about the material's surface chemistry. Using the eyepieces and a fibre-optic cable, the X-ray beam can be targeted at very specific areas of an object's surface. The whole process must be carried out in a vacuum – hence the thick walls of the chambers – because electrons cannot travel very far through air.

"The data collected could lead to improvements in products like plastics, coatings, fibres, pharmaceuticals and ceramics," says Dr Graham Bushnell-Wye, who works with the spectrometer at Cheshire's Daresbury Laboratory.

Reflected glory

At this magnification (over 20,000 times), the velvety wing of a Blue Morpho butterfly (*Morpho peleides*) doesn't look particularly colourful. In fact, even the faint colouration seen in this scanning electron microscope image has been added. Nonetheless, the naked eye would see a metallic, shimmering blue wing.

The Blue Morpho's stunning display isn't caused by any coloured pigments in its wings. Instead, when waves of light at the blue end of the spectrum strike the regularly spaced ridges on the wings, they are reflected in such a way that the waves add to one another, making the reflection stronger.

"With other colours this constructive interference, as it's known, doesn't happen," says physicist Dr Ian Hooper at the University of Exeter. "Those wavelengths are absorbed by pigments within the wing."

Japanese company Teijin Fibers developed a proprietary textile called Morphotex, which has the same light-reflecting properties. It was used in a dress by designer Donna Sgro.

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April 2012

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The latest intelligence

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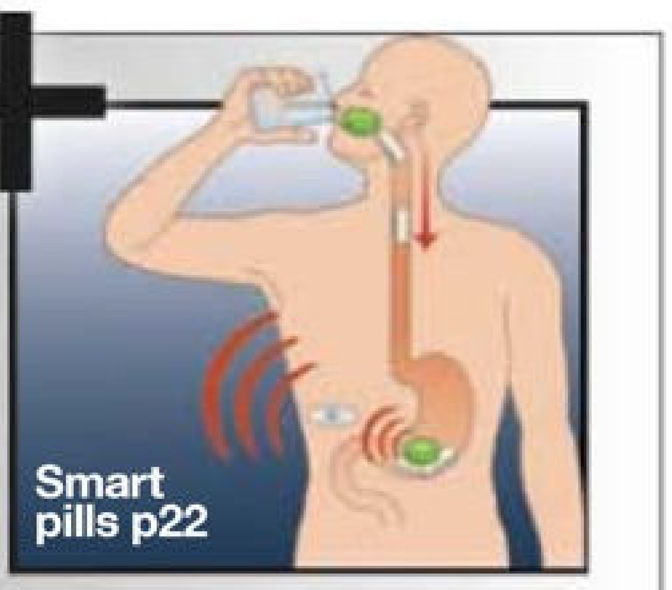


Smart pills p22

Fill your tank with seaweed

Marine algae could become new car fuel following scientific breakthrough

Forget drilling into the ocean floor to tap into ever-dwindling supplies of oil, because there could soon be a new fuel source beneath the waves – seaweed. A technique has been developed to convert the sugars in seaweed into a fuel that can be used to power cars, using a microbe that normally lurks inside your gut.

Biofuels are currently produced from crops such as corn and sugarcane, but these sources are also in demand for use as food, and their production requires large amounts of land, fresh water and fertiliser. Seaweed requires none of these and has the added advantage of not containing lignin, a strong strand of sugars that stiffens plant stalks but is difficult to turn into biofuel.

That said, the predominant sugar molecule in seaweed, alginate, has also proved difficult to break down. "Current technologies have been unable to metabolise or 'unlock' all of the sugars in seaweed," says Yasuo Yoshikuni, co-founder of biotech company Bio Architecture Lab in California. But now researchers at Bio Architecture Lab and the University of Washington have managed to spot alginate-breaking genes in microbes and add them to *Escherichia coli* (or *E coli*), the gut bacterium that's best known as a food contaminant but also has a genome which can be easily manipulated. The custom-built *E coli* went on to produce bioethanol from kombu, an edible brown seaweed. Bioethanol can be blended with petrol and used in engines with little or no modification, or used as pure alcohol in modified engines.

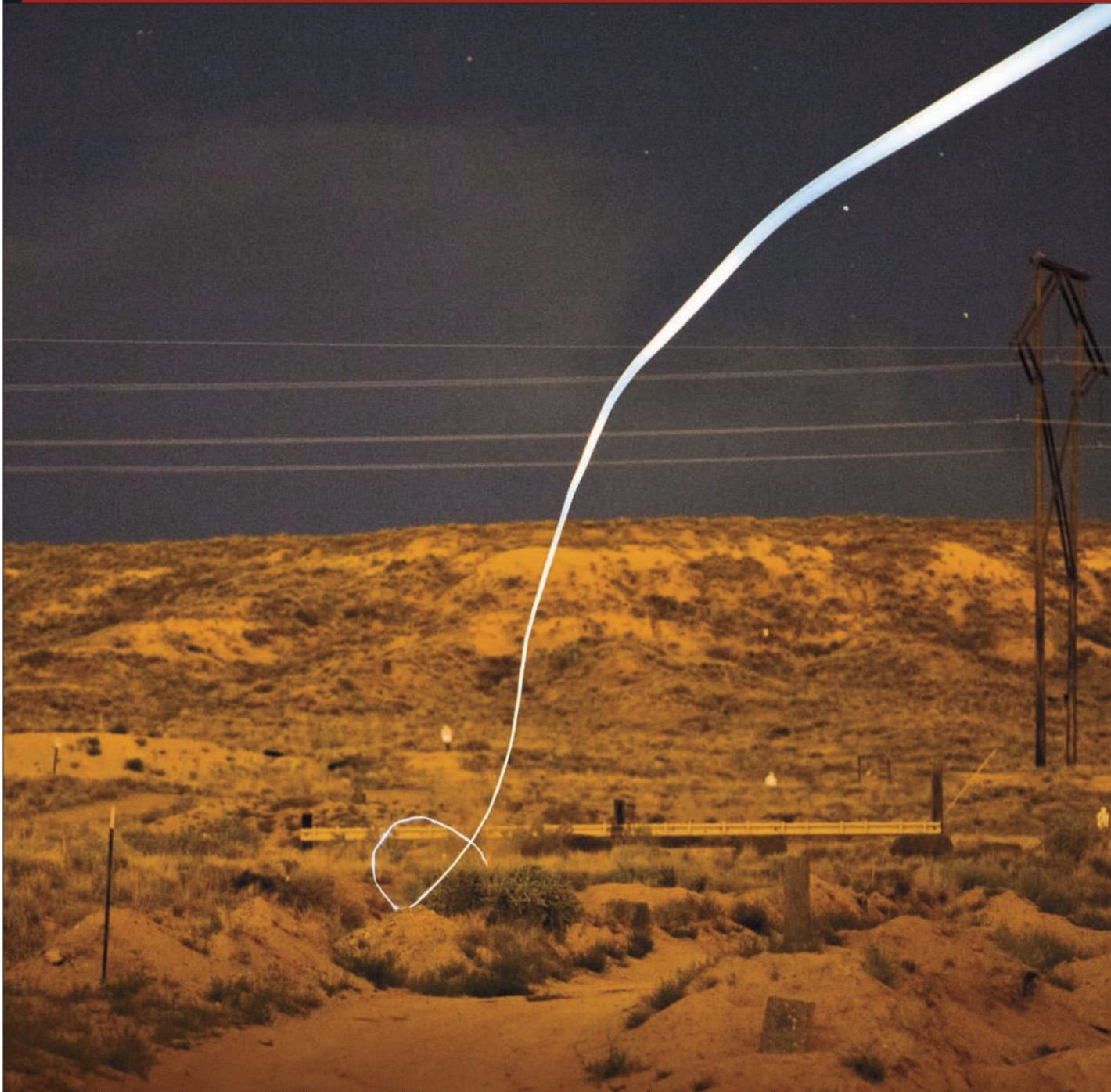
"Brown seaweed has a high sugar content and does not compete with food crops for land or water use," says Yoshikuni. Brown seaweed also grows more quickly than the red or green species.

The only potential stumbling block is growing enough of the stuff. Several thousand tonnes are farmed annually for food, but if it is going to be used widely as a fuel, billions of tonnes would be required. But Bio Architecture Lab is still forging ahead, launching a seaweed biofuel pilot project in July. It hopes to commercialise seaweed-sourced fuels within three to four years.

Hidden cost of biofuels

Biofuels are an attractive alternative to fossil fuels because they are renewable and, it is often stated, produce lower carbon emissions. But new research suggests that when all factors are taken into account, some biofuels, particularly biodiesels, could actually cause *more* greenhouse gas pollution than fossil fuel diesel. Biofuel carbon emission calculations don't traditionally take into account the fact that when farmland is given over to growing biofuels, wild areas are often cleared to produce crops the biofuels have displaced. A seaweed biofuel could solve this problem, as no arable land is required to produce it.

GETTY



SANDIA NATIONAL LABORATORIES, DARRYL PITT

The bullet that can't miss

Self-guided munitions that can find their own way to a target have always been confined to large missiles – until now. A bullet has been developed that's just 10cm long and a little over 1cm wide, yet is packed with enough clever electronics that it can direct itself towards a target over a mile away, at speeds of over 730 metres per second.

Inside the bullet's nose is an optical sensor that picks up the location of a laser shining on a target. The sensor relays that information to a CPU, which runs correction algorithms and can send up to 30 messages a second to a set of electromagnetic actuators. These move small fins on the bullet's surface, adjusting its flight path.

The design is the brainchild of engineers at the US government-funded Sandia National Laboratories in New Mexico, who spent three years and a million dollars to come up with a prototype bullet. This early incarnation was fitted with a tiny LED, which allowed the designers to follow its progress – and, as this time-lapse photograph shows, it proved its capabilities in night-time field tests.

The engineers now have their sights set on working with private companies to hone their design, to make it cheap enough for army types to spew out of a machine gun.

MONTH IN NUMBERS

190 million

years old is the age of dinosaur nests discovered in South Africa. The 10 nests are around 100 million years older than any previously found.

100,000

km is how close a comet got to the Sun before burning up. Astronomers were able to watch its final moments by stringing together images from NASA's Solar Dynamics Observatory.

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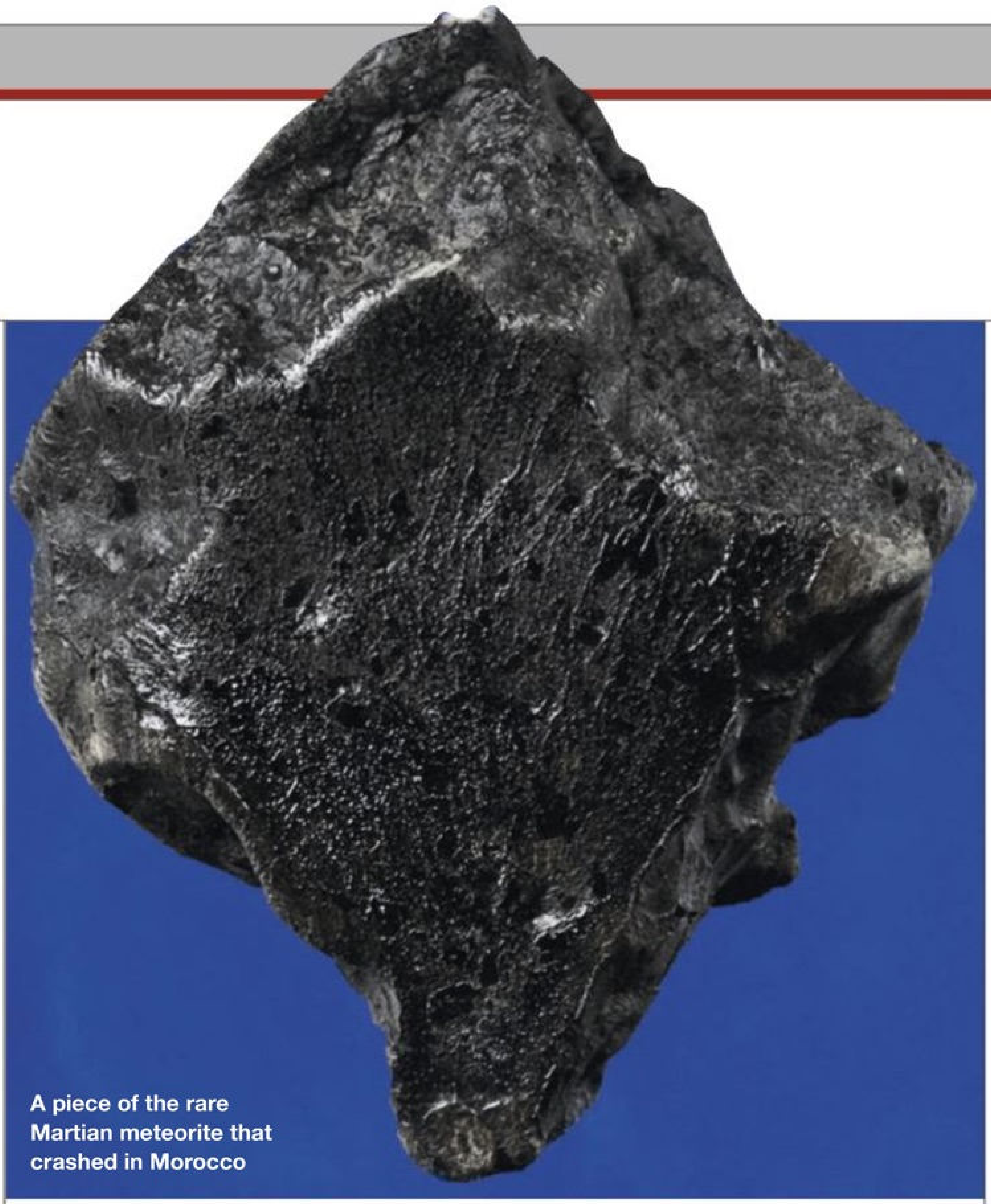
new species have been found in the forests of Suriname, South America. They include the cowboy frog, which has a spur-like structure on its 'heel'.



A piece of the rare Martian meteorite that crashed in Morocco

Martian meteorite set to reveal Red Planet's secrets

UK team will be first to study rare space rock

British scientists have begun studying a rare meteorite to reveal more about the history of Mars. The rock, named Tissint after the Moroccan area where it crashed in July, was recovered from the ground just five months later – not enough time to be too contaminated.

"The Tissint sample is probably the most important meteorite to have landed on Earth in the last 100 years," says Dr Caroline Smith, curator of meteorites at the Natural History Museum in London.

A 1kg fragment was bought by an anonymous benefactor and donated to the Museum, whose scientists will get first crack at studying it before sharing samples with researchers from around the world. "It's an amazing acquisition," Smith tells *Focus*. "It will give us much better insight into the geological and environmental history of Mars."

An analysis of the rock's oxygen isotopes revealed its Martian origin. It would have been ejected from Mars when an asteroid struck the planet, staying in space as debris before being attracted by Earth's gravity. Of 41,000 officially recognised meteorites, 61 come from Mars and the Tissint rock is only the fifth witnessed to fall.

The meteorite is igneous, formed when molten rock solidified. Dr Tony Irving of Washington University, who performed some initial analysis on the sample, doesn't think there's much chance of finding fossilised life within it. "You wouldn't look for fossilised life on Earth in a lava flow," he says.

But the British team could reveal whether minerals have been affected by water or contain elements such as carbon. They're also using CT scans to study the meteorite's internal structure and to find gas bubbles trapped in the rock during its formation.

"We're not looking for microbes," says Smith. "We're looking for the chemical and environmental signatures to indicate whether Mars, at some point in its past, may have provided a suitable environment for life to exist."

Soon you'll be able to emblazon custom messages across your t-shirt in lights, thanks to a new kind of lithium-ion battery that can be woven into fabric.

Exercise has been found to work some of its wonders by increasing the activity of autophagosomes, microscopic structures that form around worn-out cells to break them down. An increase in 'autophagy' is known to slow the process of ageing.

The current increase in solar activity will help to clear away some of the trash that orbits Earth. Increases in solar radiation warm the atmosphere's outer layer, causing it to expand. This puts atmospheric molecules in the path of space junk, reducing its velocity and causing it to re-enter the atmosphere.

GOOD NEWS

BAD NEWS

Bacteria that can resist antibiotics have been found in Antarctic seawater. A quarter of the *E.coli* bacteria collected at research stations carried genes for the enzyme ESBL, which can destroy antibiotics. The research shows how far antibiotic resistance has spread.

Many of the world's biggest trees are dying off because they are vulnerable to the increase in wind turbulence associated with being on the edge of a wooded area – an increasingly common occurrence due to widespread forest fragmentation.

Perfluorinated compounds (PFCs), chemicals used in food packaging, reduce the effectiveness of vaccines in children exposed to high levels of PFCs in drinking water or seafood.

INSIGHT

Raman spectroscopy airport scanner

What's that?
It's a device built by British company Cobalt Light Systems, which can detect the contents of bottles without them being opened. The technology should bring an end to the 100ml limit on bottles that can be carried aboard aircraft. The limit was introduced after terrorists plotted to carry hydrogen peroxide-based explosives aboard aircraft flying from Britain to the USA.

How does it work?
Bag-checkers will pop a passenger's bottle into the microwave oven-sized INSIGHT100 and five seconds later they'll be told whether the bottle's contents are sunscreen or nitroglycerin. The device uses a technique called spatially offset raman spectroscopy, which shines a near-infrared laser into a bottle. Some of the light reflected back is shifted in wavelength by the molecules inside the bottle, and this shift reveals what the molecules are.

Who's behind it?
Cobalt Light Systems is a spin-off from the Government's Central Laser Facility in Oxfordshire, where scientists use lasers to study materials at a molecular level.

When can we expect to see this scanner at an airport?
INSIGHT100 is one of several bottle-scanning technologies being trialled, and has just passed European civil aviation security standards with flying colours. In Europe, the technology will be introduced from April 2013.

ROUND UP

This month's top science stories from around the globe

SEISMOLOGY

Airgun predicts earthquakes

Chinese scientists hope that monitoring the seismic waves generated by a giant 'airgun' will help them make better earthquake predictions. In an early test the gun, which consists of four large tanks each holding 33 litres of air, was lowered into a small reservoir and fired, generating ground motion equivalent to a magnitude 0.5 earthquake. The team plans to fire the gun each week for three years to see how changes in the speed of the resulting waves are indicative of changing stresses along fault zones.

HEALTH

Sunlight fights food allergies

Exposure to sunlight appears to reduce the risk of children developing food allergies and eczema. A study of Australian children found that those living in the south of the country, where there is less sunlight, are twice as likely to develop eczema as those in the north. There is also a link between latitude and the incidence of peanut and egg allergies. The next step is to discover which factors, such as differences in temperature and vitamin D levels, are the main drivers behind the relationship.

MOLECULAR BIOLOGY

Antiseptic tears explained

A century has passed since biologist Alexander Fleming first found antiseptic proteins in tears. But now the way in which these lysozymes devour the cell walls of bacteria has been discovered. Scientists at the University of California, Irvine, listened in to the antics of lysozymes using a carbon nanotube, a tiny cylinder of carbon atoms that acts like a microphone. The lysozymes bite through a bacteria's cell wall, eventually creating a big gash which causes the bacteria to explode.

CHEMISTRY

Electricity from cockroaches

A future of sensor-toting cyborg cockroaches being sent to spy on the enemy has taken a step closer after scientists in the US developed a technique to hijack their metabolism and produce electricity. Two electrodes were placed in a roach. At the anode, an enzyme was added that breaks down a sugar produced by the bug, trehalose, forming glucose. A second enzyme oxidizes this, releasing electrons. Potentially, this electron flow could pass through a sensor en route to the cathode.

WILDLIFE

Illusion impresses females

A male Great Bowerbird's chances of mating with a female rise the more successful it is at creating a visual illusion. Australia's male bowerbirds construct two walls of twigs – a bower – and place small objects at the front and larger ones at the back, so the bower appears smaller than it really is to a visiting female. It is thought the 'forced perspective' illusion causes the male to appear bigger than he is, and the objects he wafts around to pulsate in size, grabbing the female's attention.

GEOLOGY

Diamonds' frothy ascent

Diamonds are formed at depth and rise to the Earth's surface. That's long been known, but now Canadian and German scientists have solved the mystery of how they rise quickly enough to avoid being burned up in zones of high pressure. Magma carrying diamonds towards the surface encounters rocks containing silica-rich minerals. When this happens, the addition of silica reduces the amount of carbon dioxide that can remain dissolved in the magma. So large quantities of gas bubble out, causing the magma to rise more quickly.

You've got to hand it to the Great Bowerbird – that really is a great bower

UNIVERSITY OF STRATHCLYDE, THINKSTOCK, NASA, DEAKIN UNIVERSITY, COBALT LIGHT SYSTEMS

A new paint uses carbon nanotubes to detect structural faults electrically

NANOTECHNOLOGY

Smart paint can detect faults

A paint that can detect microscopic faults in structures ranging from wind turbines to bridges has been developed. The paint, developed at the University of Strathclyde, is made up from fly ash, a material produced when coal is burned, mixed with carbon nanotubes – tubes of carbon atoms. The nanotubes carry an electrical current. When they start to bend as a fault develops in the structure beneath, their conductivity changes – a warning sign picked up by embedded electrodes.

GENETICS

Sex traits are unique

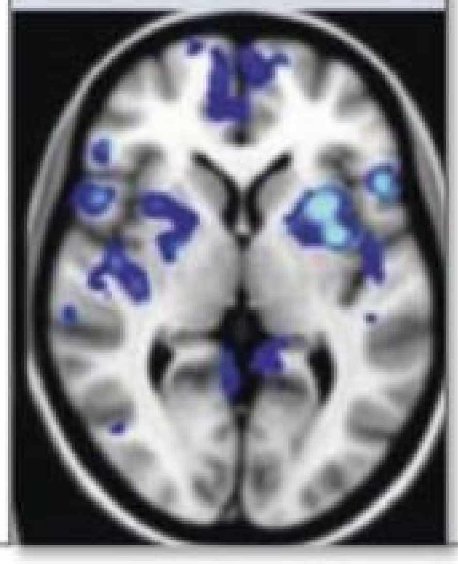
The different behavioural traits seen in men and women are controlled by their own individual genes. Scientists have known for some time that certain genes are switched on and off differently in male and female brains – and the pattern is determined by hormones. But now, in tests on mice, scientists at the University of California, San Francisco have been able to manipulate individual behaviours, such as a desire to pick fights or a propensity to care for young mice, by switching these genes on and off individually.

MAGIC MUSHROOMS UNMASKED

It seems that far from increasing activity in the brain, as had always previously been assumed, the active ingredient in 'magic mushrooms', psilocybin, actually decreases activity in key parts of the brain.

Professor David Nutt (former head of the government's Advisory Council on the Misuse of Drugs) and colleagues at Imperial College London gave 30 volunteers a moderate dose of psilocybin as they lay in an fMRI machine which detects activity in the brain by monitoring the flow of blood. They found activity decreases in connection hubs, such as the medial prefrontal cortex (mPFC), that control the flow of information across the brain.

The results suggest that psilocybin could potentially be of clinical use as an anti-depressant, as the condition is associated with an over-active mPFC.



NEWS IN BRIEF

- Boa constrictors stop squeezing their prey when they detect that its heart has stopped beating. Researchers at Dickinson College in the US fitted dead rats with artificial hearts – two tiny water-filled balloons connected to a pump. When the 'heart' stopped beating, the constrictors stopped constricting – an activity that takes seven times the energy a snake uses at rest.

- NASA's Kepler space telescope could be used to hunt for exomoons – moons of planets orbiting stars other than our own. The telescope looks for slight drops in light received from stars as planets pass in front of them. To ensure these drops really are exoplanets rather than just random dips in brightness, Kepler looks for drops at regular intervals. But now US and Dutch astronomers want to look for slight variations in the frequency of such dimming events which could indicate the presence of another object besides the star, such as an exomoon.

- The winged dinosaur that's often said to be a link between reptiles and birds had black feathers. Biologists from the US and Germany analysed the fossilised feather of an Archaeopteryx, a carnivore that lived in what is now Germany 150 million years ago, using a scanning electron microscope. They spotted pigment-producing structures called melanosomes and, comparing them to those of living birds, say that the feathers were almost certainly black.

- It may be possible to detect autism in six-month-old babies using a brain scan, long before the first behavioural symptoms start to appear. An international team of scientists recorded brain electrical activity in over 100 babies as they watched an image of an adult's face whose eyes moved towards, then away from the child. Those who did not develop autism at three years showed much larger spikes in brain activity than those who did.

Your inner voice laid bare

Imagine a device sitting on your brain that can read the words you are thinking, then speak them out loud without you moving your mouth. That's the rather unnerving possibility opened up by new research in which patients' minds were 'read'.

Neurologists at universities in the US were given a rare opportunity to study the brains of conscious patients, who were undergoing assessment before having tumours or seizure-causing tissue removed. They attached a series of sensors directly to a region in the patients' brains called the posterior superior temporal gyrus. They were used to record the activity in brain cells, or neurones, when the patients were played 47 real or invented words and phrases.

The researchers were able to recognise those aspects of speech, such as sound frequencies and the timing of syllables, that the brain uses to interpret which words are being said. Algorithms then allowed the original sounds of the words to be recreated from the pattern the neurones fired in. The recreated words aren't good enough to be recognised by a human listener – they can only be made out when the original and reconstructed sound patterns are compared visually. But it's still an incredible feat.

"It really is very dramatic and technically difficult," says Professor Sophie Scott, a neuroscientist at University College London. "It's such an exciting time to work in auditory neuroscience, because we've lagged behind the visual system for so many years."

The neurologists behind the study believe bionic devices to help speech-impaired patients to communicate could be commonplace in 10 years' time.

GETTY, JOHN MASON/ARDEA

Bat's ugly nose explained

Pretty it may not be, but it seems that the large, misshapen nose of a horseshoe bat helps it to navigate at night. The nose's many folds have been shown to focus the sound beams emitted in calls, reducing the amount of echo interference that comes back from the clutter of a forest.

Bats fly and feed at night by emitting sound and detecting the echoes that bounce back. To find out what effect the nasal folds have on sound transmission, biologists at the University of Antwerp in Belgium developed models of the bat's head and facial features. Contradicting previous research that found the folds focus only certain frequencies of sound, the new research shows that all frequencies are focused, so that stray beams will not confuse the signal the bats get back.

LOOK BACK

15 YEARS AGO

A Pegasus rocket carries the remains of 24 people, including *Star Trek* creator Gene Roddenberry, into orbit in the first space burial.

40 YEARS AGO

Astronaut John Young reaches 17.7km/h (11mph) in his lunar rover during the Apollo 16 mission, setting the lunar land speed record.

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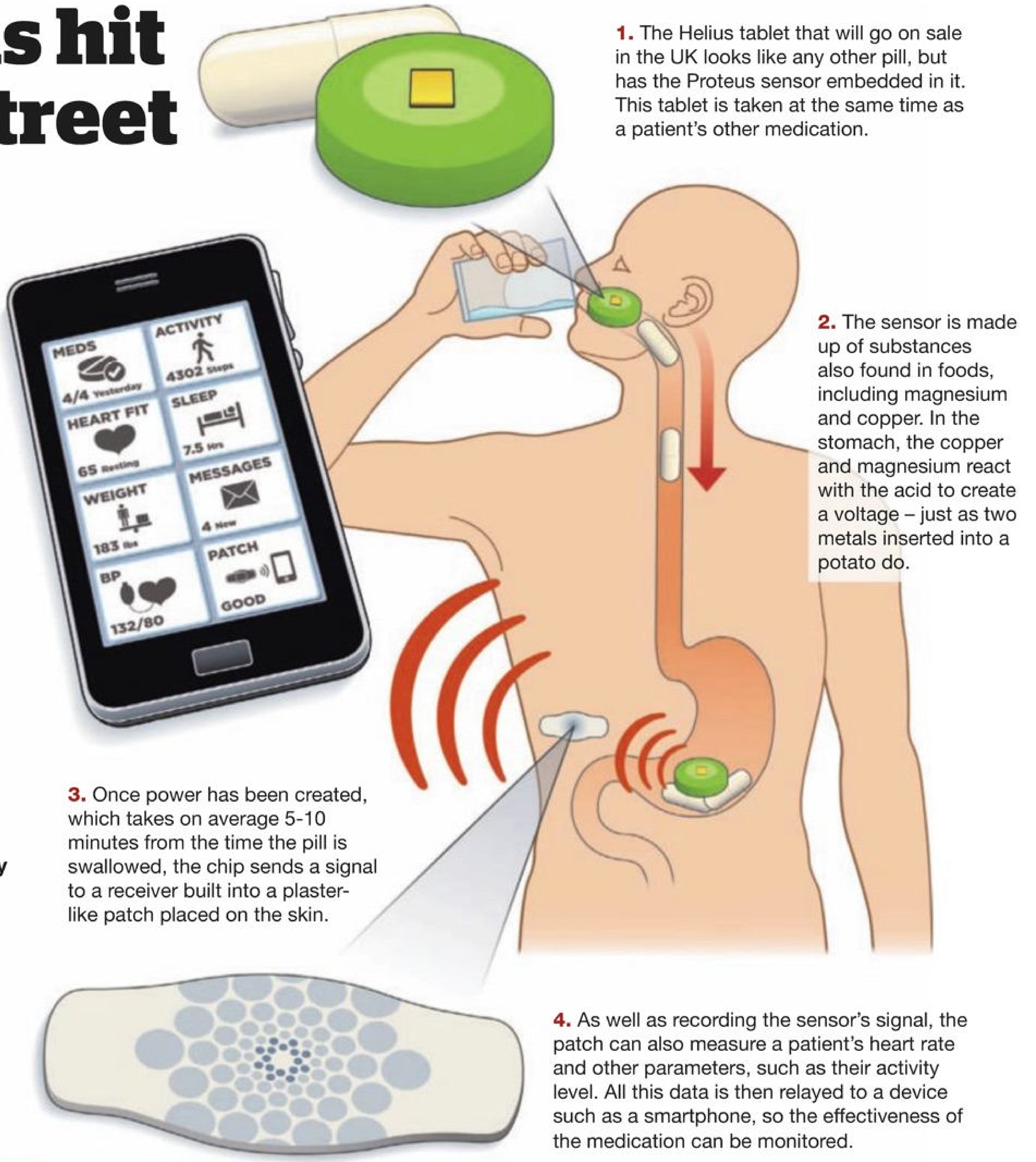
Smart pills hit the high street

Back in the 1980s, NASA developed a 'thermometer pill' to monitor the body temperature of its astronauts. More recently, elite athletes including American footballers and cyclists have taken to chowing down on them to get vital data on their core temperature. But soon the 'intelligent pill' will be arriving on a high street near you.

Later this year, a microchip that can be swallowed will go on sale in the UK. Rather than measuring a patient's body temperature, the chip – developed by California-based Proteus Biomedical – will provide a digital record of when they have taken their medication. The chips, which measure just 0.5mm across, will be fixed to a dummy tablet that will be taken with a patient's medicine.

The 'ingestible event marker' will allow doctors to monitor whether a patient has taken their tablets correctly – the World Health Organisation estimates that one in two people currently don't. A separate skin patch will record parameters such as heart rate, so the effects of the pills can be monitored too.

Proteus plans to launch its Helius intelligent pills in collaboration with Lloydspharmacy in September.



1. The Helius tablet that will go on sale in the UK looks like any other pill, but has the Proteus sensor embedded in it. This tablet is taken at the same time as a patient's other medication.

2. The sensor is made up of substances also found in foods, including magnesium and copper. In the stomach, the copper and magnesium react with the acid to create a voltage – just as two metals inserted into a potato do.

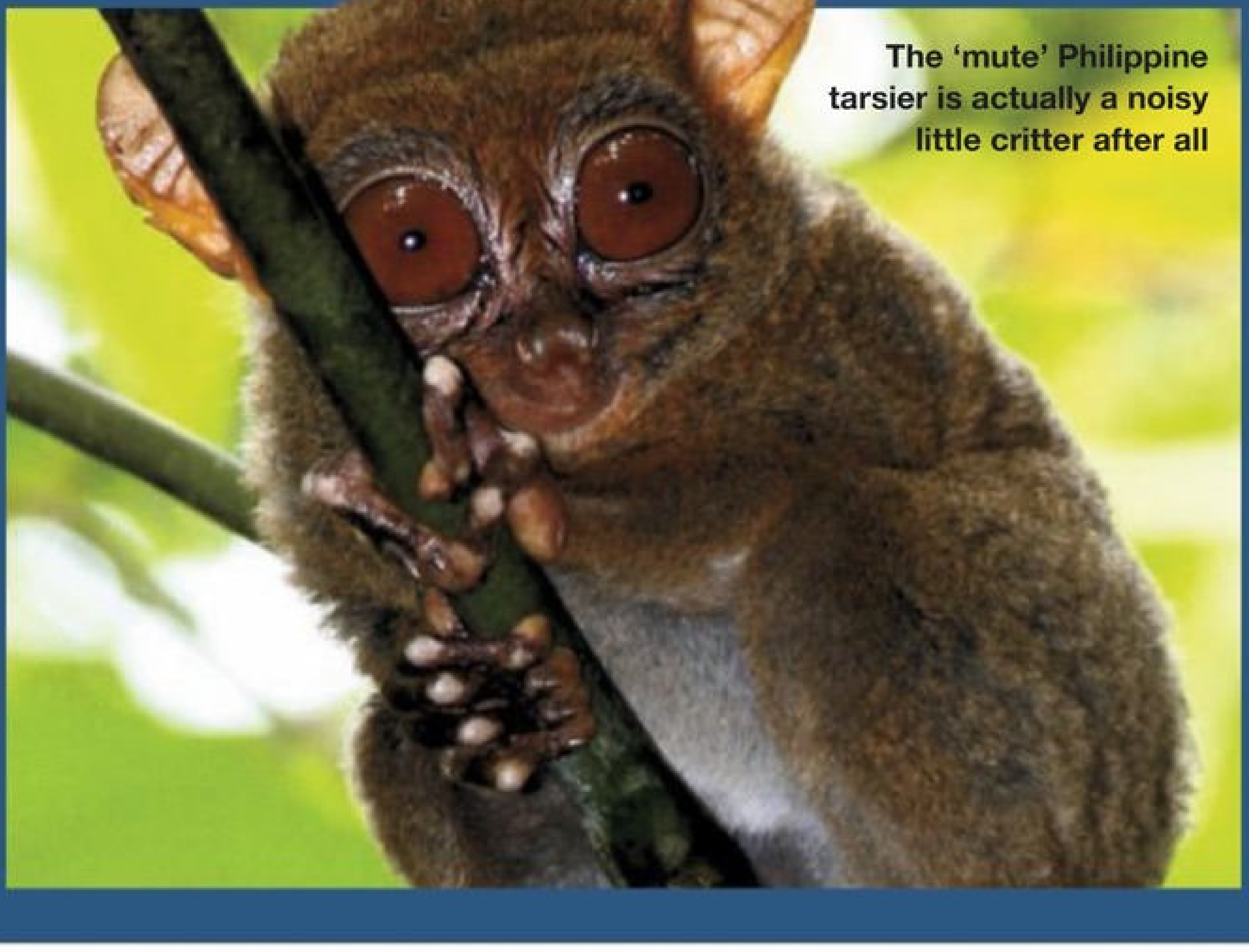
3. Once power has been created, which takes on average 5-10 minutes from the time the pill is swallowed, the chip sends a signal to a receiver built into a plaster-like patch placed on the skin.

4. As well as recording the sensor's signal, the patch can also measure a patient's heart rate and other parameters, such as their activity level. All this data is then relayed to a device such as a smartphone, so the effectiveness of the medication can be monitored.

...and finally

Primate's silent screams

Tiny primates found only in the Philippines communicate in such high-pitched tones that their squeaks are inaudible to the human ear. Until recently they were thought to be mute – but that's not true. When a Philippine tarsier was put in front of a bat detector its screams, which range from 67 to 79kHz, came through loud and clear. Human hearing tops out at 20kHz. While other primates have ultrasonic elements to their calls, the tarsier is the first known to squeak entirely ultrasonically.


The 'mute' Philippine tarsier is actually a noisy little critter after all

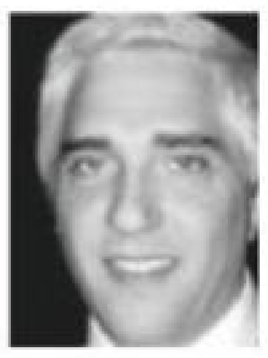
Elevated by power

Feeling powerful makes you walk tall – in your mind at least. Scientists in the US carried out tests in which volunteers were made to feel either powerful or less in control. In one test, some volunteers were asked to recall an incident when they had power over someone else. They were then placed next to a pole that was 20 inches (50.8cm) taller than them. The 'powerful' volunteers judged the pole to be on average just 19 inches (48.3cm) taller, while the 'powerless' judged it to be over 25 inches (63.5cm) taller.

GETTY, NATHANIEL DOMINY, ILLUSTRATION BY RONALD WILSON

THE BURNING QUESTION

Steven Novella is Assistant Professor of Neurology at Yale University School of Medicine in the US, and host of the podcast *The Skeptics' Guide To The Universe*



With Steven Novella

Should we use 'electric shock' treatment to improve academic performance?

The brain is a chemical and electrical organ, and an amazingly complex hunk of meat. For about the last century we have been studying ways to alter its function to compensate for disease, damage and dysfunction, largely through pharmacological means. More recently we've developed drugs that can enhance our brains' abilities even when there is no fault to correct. But now we are at the beginning of a new method for altering brain function – through direct electrical stimulation.

Researchers at the University of Oxford have found that small electric currents applied to the brain can make healthy people more capable. They read better, are better at solving problems and remember more. It's research that could herald an era of cheap, convenient brain augmentation.

In transcranial direct cortical stimulation (tDCS), the technique used at Oxford, specific frequencies of electrical current are used to either increase or decrease the activity of specific parts of the brain. This has proven a useful research tool, helping researchers figure out how different parts of the brain contribute to overall brain function. To act as a therapeutic tool, the activity of specific brain regions involved in specific tasks, such as reading, maths, or memory has to be increased while performing the relevant task.

Studies like the one in Oxford have consistently shown that tDCS, when applied in the right way to the correct part of the brain, can improve function. Research in this field is still preliminary, but very encouraging. The technique appears safe so far, but more long-term follow-up would be reassuring. Would routine brain stimulation tire out the brain cells, or reduce baseline function, creating dependence on the stimulation?

The real world applicability of tDCS also needs to be further studied. Will it improve a student's long-term academic performance, for example? tDCS should still be considered experimental, and more research is necessary to see if the results hold up under larger rigorous studies.

There are several advantages to tDCS, so it is worth researching further. It is easy to design controlled trials, because sham tDCS (stimulating the wrong location at too low a power or frequency) is easy to perform. It is therefore easy to 'blind' the subjects or the researcher as to which subject is getting the real treatment and which one is getting the sham or placebo treatment. The technique is also non-invasive, and appears so far to be very safe. Devices that apply tDCS are also relatively cheap and portable.

"Studies have consistently shown that tDCS can improve brain function"

It is these attributes that make tDCS ripe for abuse, however. It would be easy for unscrupulous snake-oil salesmen to sell cheap tDCS devices with alluring claims that are not backed by good research. Further, improper application can have the wrong effect. It can either stimulate the wrong part of the brain or inhibit brain activity, interfering with normal brain function in unpredictable ways or even inducing a seizure.

Public acceptance may also be an issue. Some may find tDCS preferable to using drugs to alter brain function, while others may see it as 'hacking' into the brain. I suspect there are those who simply will not like the rather blatant reminder that we *are* our brains. Our thoughts, memories, moods, and feelings are all the result of electrical currents in our brains, currents which can be altered with a small electrical device.

It is plausible that this research will one day lead to teachers telling students to put on their thinking caps, and meaning it literally.

WHAT DO YOU THINK?

Would you ever allow your brain to be artificially stimulated electrically?

post@sciencefocus.com

The Analyst

Robert Matthews

We need a way to make sense of the barrage of contradictory health claims

Flick through the pages of the Royal Statistical Society's journal *Significance* and you'll soon realise that statistics is about more than just collecting data on coal production in Albania and the like. Each issue highlights the vast applicability of statistical methods, from spotting fraud in science to predicting the next financial crash.

Recent issues have also debunked another myth: that statisticians are shy, retiring types who'll do anything to avoid a scrap. There's currently a good old spat taking place within *Significance*'s pages over something we're all familiar with: the constant stream of studies claiming to have found some health risk or miracle cure, which then turns out to be twaddle.

The row was started by two American statisticians who wheeled out some pretty shocking stats about these claims. They identified a dozen studies whose claims were then tested in carefully monitored clinical trials. The original dozen studies were said to have identified over 50 links between, for example, diet and the risk of cancer. Of these 50, the clinical trials confirmed precisely zero.

That will come as no surprise to those of us used to hearing one day that, say, coffee is lethal, and the next day that it's the elixir of life. But the researchers behind some of the studies weren't best pleased to see their claims being rubbished, and have hit back. Some accuse the authors of impugning their integrity and seeking to "wilfully misrepresent" their research.

When the dust has settled, though, the basic problem will remain. Too many observational studies – where people are simply observed to see whether diet or lifestyle has affected them, rather than a trial being set up in advance – turn out to be nonsense. But what can be done?

> *"We're used to hearing one day that coffee is lethal, and the next day that it's the elixir of life"*

The two authors suggest using independent researchers to analyse data. But I think there's a far bigger problem, and it's the method used to tell whether a finding is worth taking seriously or not.

Hardly a week goes by without our being told that, for instance, drinking more than one diet drink a day increases your risk of a stroke – to pick a real example – without any real explanation. We're meant to take it seriously because the effect is 'statistically significant'.

But as any statistician will tell you, this is often much less, well, significant, than it seems. It's often taken to mean the chances of the result being a fluke are very low, but it doesn't. And it's especially misleading when applied to inherently implausible claims.

We need some way of taking plausibility into account. And there is one: it's called Bayesian inference. Put simply, it takes the results of a new study – say, the risk of experiencing some health effect, plus or minus some uncertainty – and combines it with a range of values for this risk indicated by previous studies. If the new study is hard to reconcile with those earlier studies – if it lacks plausibility – then Bayesian methods will warn you not to take the new result too seriously.

So why aren't scientists using Bayesian inference? Many are: its power to make sense of new findings is now routinely used in fields ranging from archaeology to climatology and cosmology. But it's high time its powers were turned onto all those health claims we're constantly being bombarded with. Only then will we be able to sort the medical gold from the headline-grabbing iron pyrite.

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SEARCH: NEW HONDA CIVIC

The Insider

Henry Gee

The hunt for the source of our brains just got even more interesting

Some of the finest minds in evolutionary science have been wrestling with an important question – where did our brains come from? We humans are vertebrates, animals with backbones. As well as backbones, vertebrates are distinguished by their large, complicated brains. With a few exceptions, most invertebrates have little or no brain. And since vertebrates evolved from invertebrates, the source of the tangled mesh of nerves inside our head is not clear. Thankfully, new research sheds a little more light on the subject.

You probably won't have come across our closest relatives among the invertebrates, tunicates, unless you know where to look. These creatures have rudiments of what would, one day, be a backbone, but little else to betray their kinship with us. Most look like shapeless bags of goo anchored to rocks, extracting food by filtering seawater through their gills.

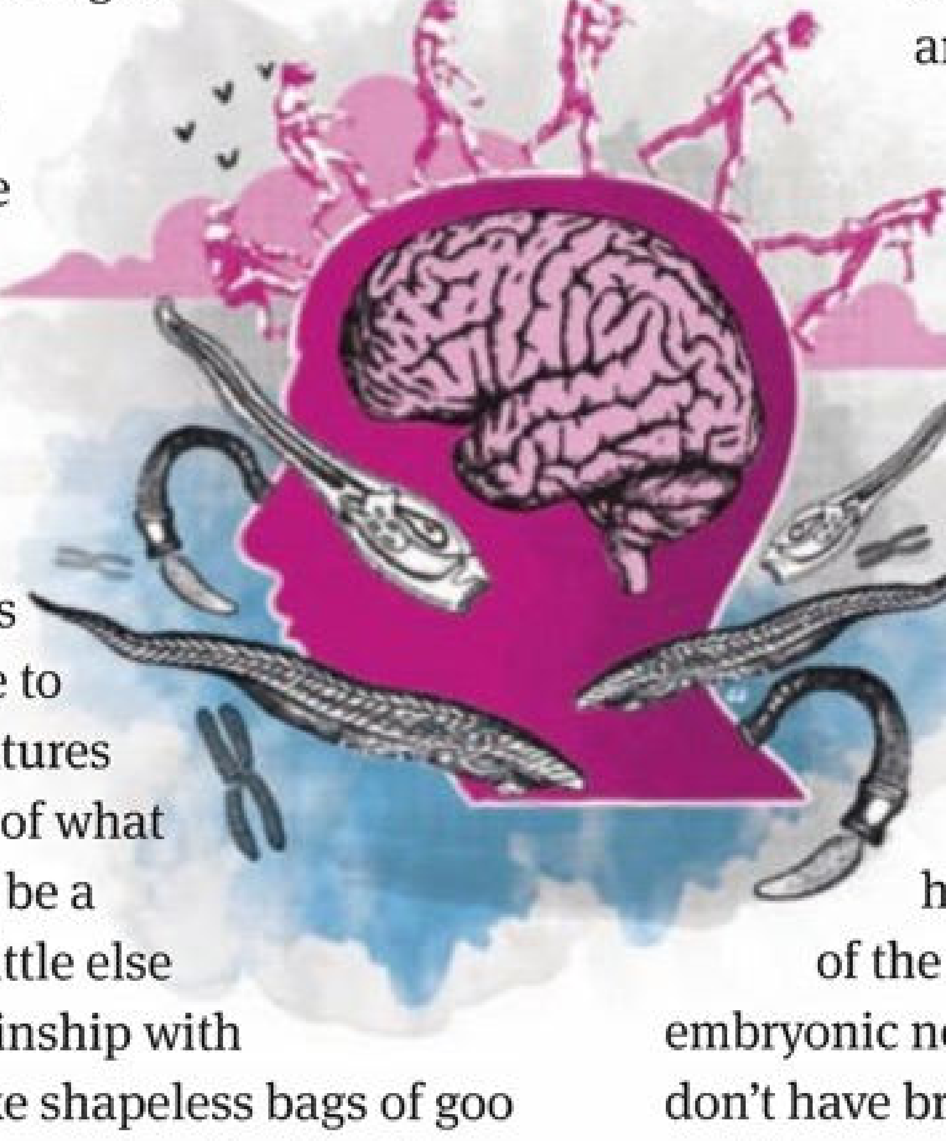
If this seems like a pretty mindless pastime, it is – tunicates have very little brain. The only clue to our relationship with them is in the tunicate larva, a tiny tadpole-like swimmer with a backbone-like stiffening rod supporting a tail and – yes – a tiny brain. So while tunicates are perfectly capable of making a brain, almost all adults have gone without.

Our next suspect in the hunt for the origin of our brain is another filter-feeding sea creature, the amphioxus. Although a more distant relative than tunicates, the amphioxus actually looks like a small fish – except that it doesn't have a head. Or does it? Work on its genome has shown that it has quite a few of the genes necessary for head formation, expressed at the front end of the animal. But like tunicate larvae, they don't go all the way.

The latest research looks at still more distant relatives – more closely related to starfishes and sea urchins than to vertebrates – called acorn worms. These creatures are revolting. They look like intestines, are covered in slime and smell vile. Like tunicates and the amphioxus, they don't have a brain. But, like tunicates and the amphioxus, there is more to them than meets the eye.

Professor Chris Lowe of Stanford University, who has been studying the genes of acorn worms for many years, has found that they have genes which in humans help organise the structure of the brain, elaborating it from embryonic nerve tissue. Acorn worms don't have brains, but they have the genes, and they are expressed in precisely the same places at the front of the animal that you'd expect, were complex brains to have formed. This research is important because it shows that the *potential* to evolve brains goes way, way back in our evolution – at least 600 million years.

This presents another riddle. Perhaps the presence of brain genes in these invertebrates shows they weren't always brainless. Could some invertebrates have evolved complex brains, but then lost them? If so, it would make having a brain not the pinnacle of creation – but rather a throwback to an earlier age.



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MEET THE COLUMNISTS

The Insider
Henry Gee
A senior editor of the respected science journal *Nature*, Henry is the author of several books, including *The Science Of Middle Earth*.

The Eco-sceptic
Tom Heap
Tom is an expert on all things green. He presents *Panorama* on BBC One and *Costing The Earth* on Radio 4, which questions accepted truths on green issues.

The Analyst
Robert Matthews
After studying physics at Oxford University, Robert became a science writer. He is a visiting reader in science at Aston University.

The Medic
Michael Mosley
After training as a doctor, Michael joined the BBC to become a presenter, writer and producer. He's *The One Show*'s science man and presented *The Story of Science*.

The Eco-sceptic

Tom Heap

Let the sphagnum bombardment begin

From above, it looks like giant fingernails have gouged the surface of the moor, tearing through its green vegetation to reveal the black peaty flesh beneath. Acid rain has led to the destruction of vast amounts of peat in the Peak District, leaving deep scars in the landscape. But now plant science is fighting back – by helicopter.

There is as much carbon locked up in the peat bogs of the UK as there is in all the forests of this country, France and probably Germany put together. If healthy, they could capture more. But Derbyshire and South Yorkshire had the misfortune to be beside the birthplace of the coal-fired industrial revolution. The consequent emissions rained sulphuric acid and coal dust on the hills for nearly 200 years, killing what grew. Stripped of its green armour, rain has washed peat away, leaving gullies four metres deep.

But over the horizon comes the air cavalry, led by a group called Moors for the Future, raining life from above using a Vietnam-era Huey helicopter. In the first wave come rocks, airlifted to make dams to block the eroded ravines; then come netting and heather mulch, to anchor the soil. The last stage will be an aerial bombardment of sphagnum moss. That spongy mat is the 'god particle' of peat bogs, but an awkward blighter for botanists. It has no roots or seeds. It spreads by spores, but only very rarely.

A team in Loughborough has now beaten most of these challenges. They have managed to micro-propagate individual plants. When they've grown to about 1mm, they pop them into a biodegradable coating with a little nutrient solution. This spring they'll load a million or so of these magic beans into a hopper beneath a chopper and spread them over the moors.

When it grows we'll turn the tide – but slowly. A healthy sphagnum bog lays down 1mm of peat per year, so the biggest scars will still take thousands of years to repair.

WHAT DO YOU THINK?

How seriously do you take health 'scare' stories reported in the media?

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Courting disaster

The article 'Power to the people' (February, p48) contained one of the most disturbing ideas I have read in any magazine or newspaper for a very long time. It was the piece regarding a micro nuclear reactor being used to power small communities, perhaps even being put into the cellar of a block of flats. The whole idea seemed to be a cross between a cold war spy thriller, with a fiendish KGB sleeper having a small atomic bomb just big enough to wipe out Kent, and a B-movie horror film, with the portal to Hell in the basement.

Another problem is that us blokes do not seem to realise that opening up a complicated piece of electronic equipment and poking a large screwdriver inside will not fix it, and does not constitute knowing what you're doing. I can imagine a future where men go down to the basement after announcing to their wives that they are "just off to mend the reactor, dear", then start hitting the thing with a small lump hammer to fix a rattle in its pipes.

On a serious note, I did think the gas-powered energy cells idea looked good, especially as our current boiler is fast approaching its use-by date. However, I feel the cost at first would be beyond the means of the average household.

Simon Elson, Burton on Trent

Yep, they're a nuclear family all right…

Computerised scientists

I've just finished reading Robert Matthews' article (January, p27) on computerised scientists, and how freeing students and their professors from the tedious chores of data analysis will allow them to work on more important things. If not an apple, surely it was the hours and hours of calculation that Newton did that gave him the insight for his more significant discoveries. Indeed, I seem to recall an article indicating it was practice, practice, practice that created genius?

Pat McDonnell, via email

Robert Matthews replies:

Historians think it was the appearance of the Great Comet of 1680, and its catapulting around the Sun by some mysterious force, that inspired Newton's theory of gravity. But by that time, it's certainly likely that he'd put in well over the 10,000 hours of focused effort some claim is needed to master a subject – in his case, maths and physics.

Atheists united

Your correspondent Keith Atkin ('Post', February) states that atheism is a dogma. As I understand it, a dogma is a belief invented by someone in authority – often, but not always, religious – which is expected to be believed implicitly, despite the fact that there is no credible evidence to support it. Atheism is therefore not a dogma, as all that atheists ask is evidence for the existence, or otherwise, of a God to be fully examined and reasoned conclusions drawn.

Science does not pretend to have all the answers, only to be diligently searching for them with honesty and integrity.

Jean Bowler, Reading

ILLUSTRATION BY VICTOR KOEN, GETTY

WHAT DO YOU THINK?

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We assume that all views submitted are for publication unless otherwise stated. We reserve the right to edit correspondence for clarity and brevity. We regret we can't reply to all the letters, emails and posts we receive.

Giant pandas: are they their own worst enemy?

Mr Atkin's objection to 'Tis the season to be jolly rational' is that he believes it could be considered insulting by non-atheistic scientists. But most of the letter was a general objection to atheism itself rather than the article. Does Mr Atkin genuinely believe that he and his non-atheist counterparts have exclusive rights to say how people can enjoy themselves during the Christmas period?

Non-atheists have a choice whether they want to go to the show, read the article or even buy *Focus*. To object would be to object to people having a choice.

Tim Smardon, Bath

Mr Atkin is missing the fact that science is the only method that produces advances in knowledge. When he says there are high-profile scientists who believe in a non-material aspect to the Universe, he seems to be under the (common) misconception that expertise in one field makes one qualified to speculate in others.

A biologist may not understand how a particular complex molecule could have arisen early in the history of life and take that as proof of some sort of designer. That same complex molecule may be easily explainable by a chemist or a quantum physicist.

David Angle, Heidelberg, Germany

GM food: for and against

I have had many conversations with people over the years about GM foods and still find it hard to believe that people are so worried about consuming these products (January, p25).

Many people have strong views about GM products but seem to be ignorant when it comes to the science. It is through scientific study that we have realised that chemicals used to keep crops free of pests and disease can be harmful – sometimes genetically, as they enter rivers and streams and are consumed by animals and ourselves. It is science that has led to a clean, harmless way of producing crops plentifully.

Louis Le Couteur, Guernsey

Interesting article but it didn't mention the other issues involved. For example, GM foods usually 'belong' to a company/corporation, who set the price and the fertiliser to be used, taking this out of the hands of the farmer. GMO producers also demand bulk buying, which cuts out small growers and maintains monoculture farming, which is bad for our planet's ecosystems. GMO plants can't be germinated from seeds or bits of potato, so growers are dependent on paying the prices of the big corporations. But yes, it would be great to benefit from tasty, chemical-free spuds – that's why I buy organic local ones.

Frances Lee, via email

Saving species

My initial thought on the 'Burning question' (February, p25) was that if 54 per cent of scientists agree there are species we should give up on, then 46 per cent think we shouldn't. I think we need to focus on preserving whole ecosystems, rather than specific high-profile species that get higher funding. It should not blur the fact that other, less loved animals need saving too. These are the species that are essential to the most beautiful and magnificent ecosystems in the world.

Grace Roberson, Worcestershire

Each species is a result of millions of years of fantastic evolution. We should at least make an effort.

Ethan Douglas, via email

As cold as it sounds, some species just can't be helped and we shouldn't focus our energies on them. To use your example of giant pandas, they're a docile species that spend the majority of their time either sleeping or eating. Conservation centres have to find ways to convince them to reproduce. It seems the species is giving up on itself, yet we're spending money to keep them alive. We should focus on endangered species whose loss would have the most impact on other species or ecosystems.

Hannah Fitzpatrick

Giant pandas have had no problem reproducing in the wild for millennia, and panda nurseries are currently enjoying a boom in cubs. But vast swathes of their natural habitat have been destroyed, so their future in the wild is bleak. ***–Ed***

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RACE TO THE BOTTOM OF THE OCEAN

A billionaire, an Oscar-winning director and a bunch of scientists all have their sights set on venturing to the deepest part of the world's oceans. **Nic Fleming** looks at why they are heading there – and what they might find

GETTY, FLPA, ILLUSTRATION BY MAGICTORCH

Almost 3,000 people have stood on the summit of Everest. Around 2,500 have been to the North Pole and some 500 have flown in space. Yet only two human beings have been to the deepest known point of the world's oceans.

Shortly after 1pm on 23 January 1960, US Navy Lt Don Walsh and engineer Jacques Piccard touched down at Challenger Deep in the Mariana Trench, which lies 500km (311 miles) southwest of the island of Guam in the Pacific. Their instruments showed a depth of 10,916m (35,814ft) below sea level. They shook hands, ate chocolate and spotted a flat fish and a shrimp through the sediment kicked up by their submersible, the Trieste. Concerns about a cracked viewing screen led them to cut their stay short, and after 20 minutes they began their ascent.

Since then, human exploration of the deepest depths of the world's oceans has been non-existent. Military submarines cannot descend below roughly 1,300m (4,200ft) and there's no current human-occupied sub that can dive deeper than 6,500m (21,325ft). Robotic vehicles can descend deeper, but that still leaves vast areas of Earth off-limits to explorers and scientists who want to experience this mysterious world at first hand.

But this will soon change. Five separate teams are developing manned vessels capable of taking humans to the deepest corners of the world's oceans. Most of the participants deny they are engaged in anything as vulgar as a race, and it's true that engineering and scientific challenges are important motivations. Yet alongside these challenges are several millionaires with big egos, engaged in a high stakes battle to be first to return to the deepest depths. It would – and probably will – make a gripping Hollywood film. There's also a hefty financial incentive. In January 2010, the 50th anniversary of the Trieste descent, the X Prize Foundation announced it would hand $10 million (£6 million) to the first team to make two manned descents to the bottom of Challenger Deep.

The race begins

Last April, Sir Richard Branson and Chris Welsh, a California-based property mogul and sailor, sat on their DeepFlight Challenger vessel and grinned for the cameras as they announced their plan to dive to the deepest parts of all five of the Earth's oceans. Their submarine was originally built for adventurer Steve Fossett, who died in a plane crash in 2007 before he could carry out what he hoped would be the first solo dive to the Mariana Trench.

"When I started, the record element was more important than it is now," says Welsh. "Now, I also have a couple of scientific Holy Grails, such as the prospect of seeing vertebrate life, and finding a carbon dioxide spring and pond." Asked if he'd still go to the Mariana Trench if one of the other teams beat him to it, though, he says: "If it turns out we'll be second or third... we would re-evaluate." ▶

"If it turns out we would be second or third... we would re-evaluate"

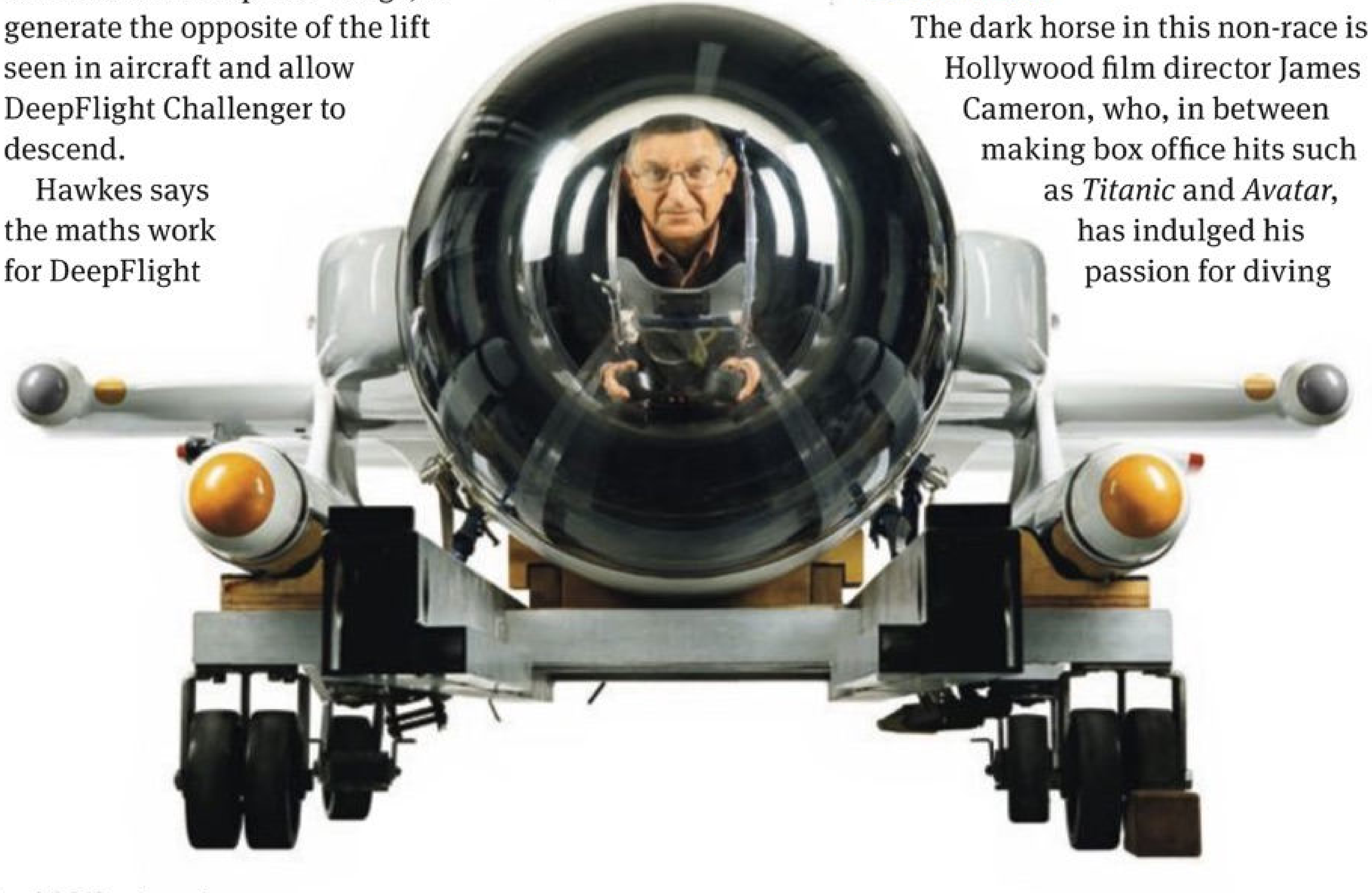
A scene from James Cameron's *Aliens Of The Deep* (2005). A documentary film based on his latest undersea adventure is a tantalising prospect

▶Some incredible sights will greet these underwater explorers. It is estimated that 80 to 90 per cent of the animals that live in the deep sea are bioluminescent, generating their own light by chemical processes. Many creatures are largely transparent. Volcanoes spew out green mud and the ocean floor is covered in a yellowish sediment known as 'biogenous ooze', that's made up of shells, animal skeletons, decaying micro-organisms and plants.

While it's Branson and Welsh who will hog the headlines, the true pioneer of the project is Graham Hawkes, a British-born engineer who is arguably the world's leading submarine designer and who created DeepFlight Challenger. Its wings, or hydroplanes, allow it to 'fly' downwards. Once fully descended it can move horizontally along the ocean floor at up to three knots for around 10km (6 miles).

"Virtually all animals in the oceans have evolved for underwater flight using fins," says Hawkes. "Air and water can be treated the same from certain engineering points of view. The same equations apply, though the constants are very different." This is why the vessel he has built has inverted aeroplane wings, to generate the opposite of the lift seen in aircraft and allow DeepFlight Challenger to descend.

Hawkes says the maths work for DeepFlight Challenger, so he considers his challenge over. But while the maths may work, the vessel doesn't, yet. Last summer its domed glass viewing bubble cracked during pressure testing, and, at the time of writing, a replacement was still being made. This has knocked the team from its perch as race favourite.



Graham Hawkes inside DeepFlight Challenger, which he built for Virgin

Secret sub

The dark horse in this non-race is Hollywood film director James Cameron, who, in between making box office hits such as *Titanic* and *Avatar*, has indulged his passion for diving and ocean exploration, as well as making documentary films including *Aliens Of The Deep* and *Ghosts Of The Abyss*. Since 2005, he has reportedly pumped almost $10 million (£6.4 million) into creating a manned sub. He's gone out of his way to avoid publicity and based his effort in Australia under engineer and cave diver Ronnie Allum. "There is a strict embargo on all information," says Allum's personal assistant. "And I'm not even allowed to tell you that."

Little is known about Cameron's design and no vessel name has been made public. But he has previously said it is based on a small spherical hull made of metal, and it passed full pressure-testing last summer. According to one interviewee, it will have 3D high-definition cameras, a large lighting array, a manipulator arm capable of taking up to 25kg (55lb) of samples and a remote operated vehicle (ROV). The level of secrecy surrounding the project has led to speculation that Cameron wants to maximise publicity for a film project.

Meanwhile a third team, Florida-based Triton Submarines, is less ambiguous about its motives. It wants to sell comfortable vessels with

BUENA VISTA PICTURES/KOBAL, THINKSTOCK X2, CORBIS X2, DOER, TRITON SUBMARINES, VIRGIN OCEANIC

space for a pilot and two passengers, capable of going to any depth in the oceans, for around $15 million (£9.6million) each. Triton founder Bruce Jones believes investors would be able to charge around $250,000 (£160,000) for trips to Challenger Deep and other deep ocean destinations.

Triton's 36000/3 vessel is based around a high-strength sphere made of borosilicate glass – the same material used in glass cookware – which is designed not only for 360-degree visibility, but also to get stronger under pressure. Light and radio frequency signals are used for communication between the internal controls and external components like the thrusters and ballast system, thereby maintaining the sphere's integrity and strength. The company hopes to test its sub in August, and is trying to raise finance. There's already been interest from the world of TV.

It is not just Triton that sees the potential of commercial riches at great depths. Last July, China's State Oceanic Administration announced that the submersible Jiaolong, named after a mythical sea dragon, reached 5,057 metres (16,600ft) below the northeast Pacific. In 2001, China ▶

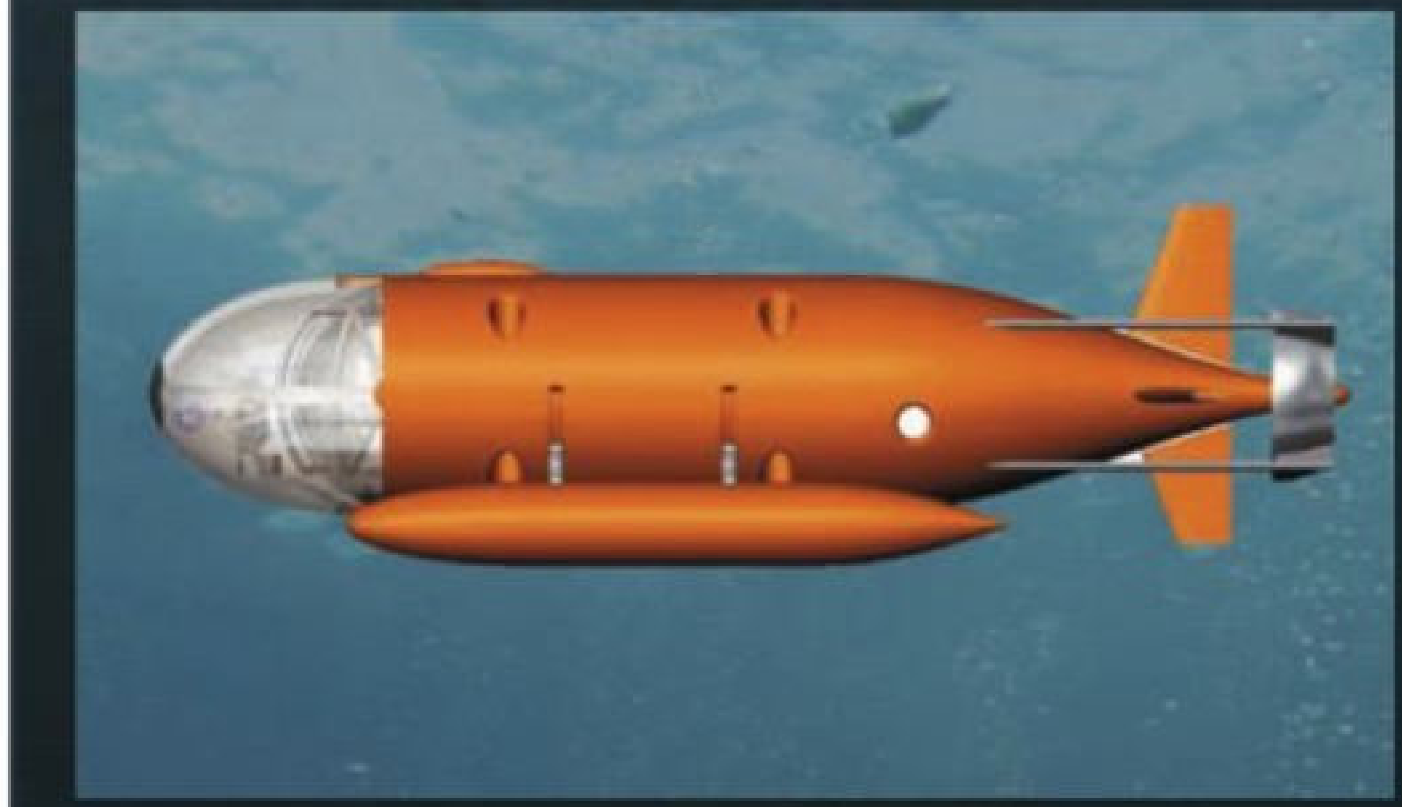
UNDERSEA CONTENDERS

The teams with their sights set on the depths

CHINESE STATE OCEANIC ADMINISTRATION

Vessel name: Jiaolong
Crew: 3 **Likely dive date:** 2012
Objective: 7,000m
Maximum depth: 7,000m

A long-term project to help China exploit deep ocean mineral and metal reserves. Jialong will briefly be the world's deepest-diving sub.



DOER

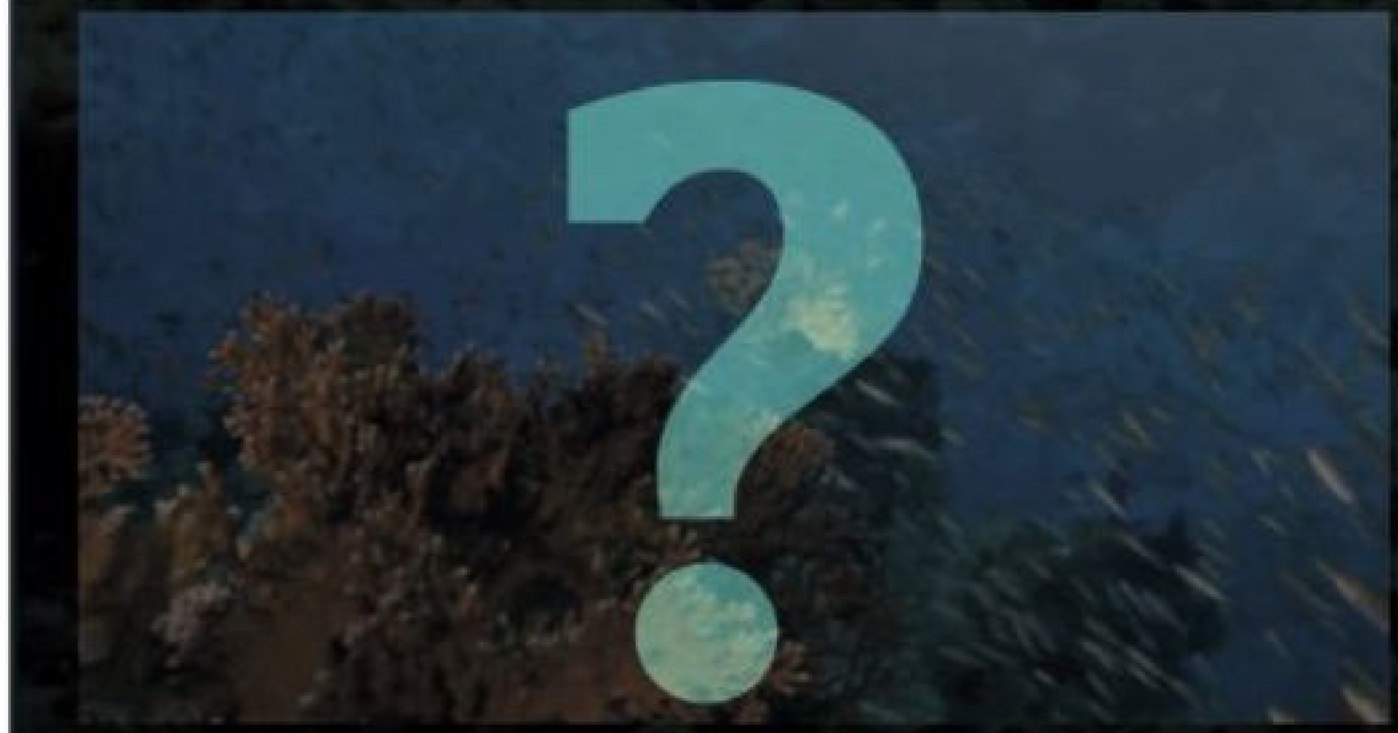
Vessel name: Deepsearch and Ocean Explorer
Crew: 3 **Likely dive date:** 2015
Objective: Mariana Trench
Maximum depth: No specific figure, but both "full ocean depth"

Both craft are described as science platforms. Deepsearch will descend quickly, allowing for an extended bottom time. Ocean Explorer will hover by rock pinnacles and walls.

TRITON SUBMARINES

Vessel name: Triton 36000/3
Crew: 3 **Likely dive date:** Late 2013
Objective: Mariana Trench
Maximum depth: 10,972m

The publicity of the challenge is being used for commercial motives. Triton plans to build submarines and sell them to operators who could offer deep ocean tours



DEEP CHALLENGE

Vessel name: not known
Crew: 1 **Likely dive date:** Summer 2012
Objective: Mariana Trench
Maximum depth: Unknown

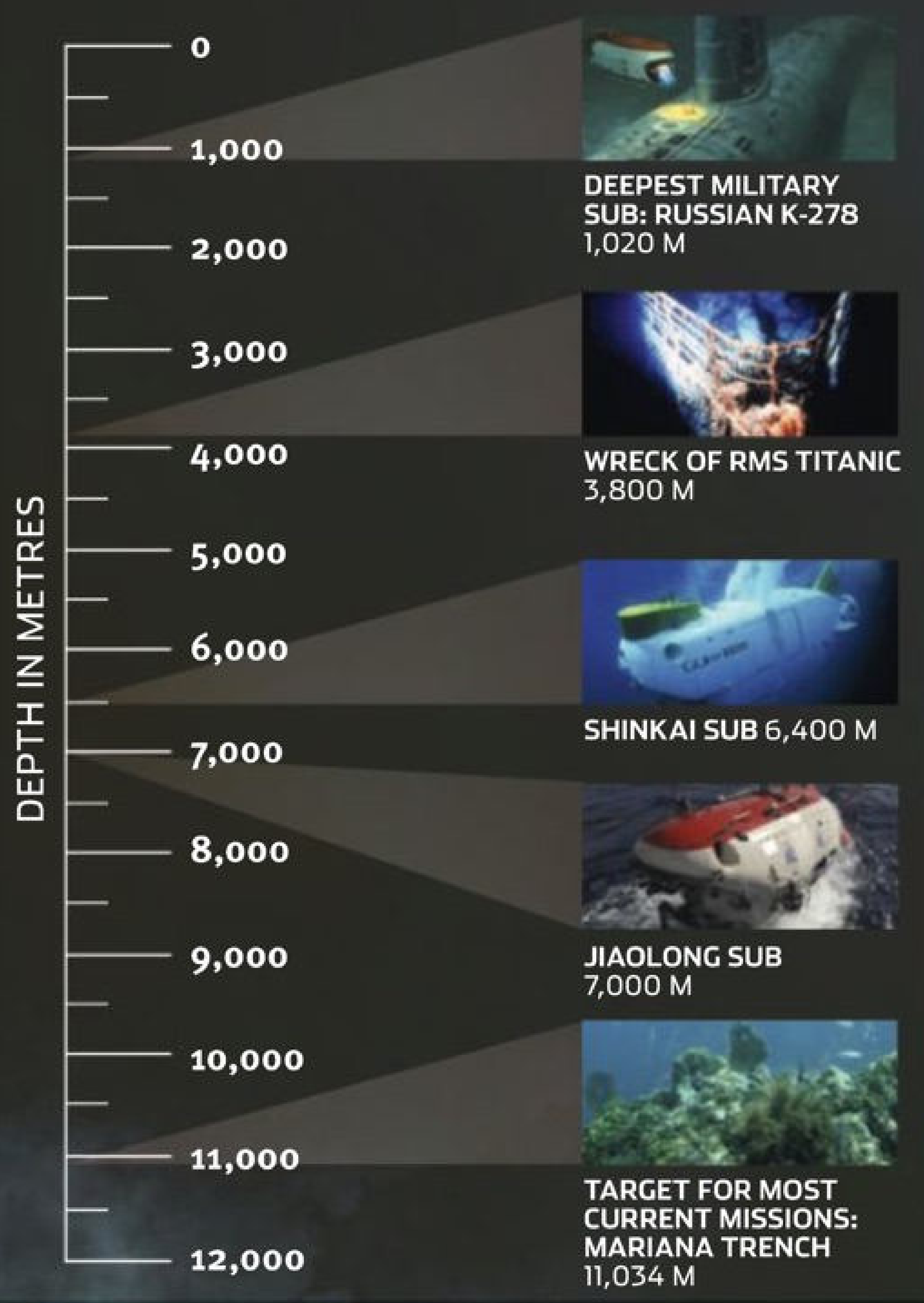
Movie director James Cameron is a keen ocean explorer. Given his background, an associated film project cannot be ruled out, though no plans had been announced at the time of writing.

VIRGIN OCEANIC

Vessel name: DeepFlight Challenger
Crew: 1 **Likely dive date:** Late 2012
Objective: The deepest parts of all five of Earth's oceans, with the Mariana Trench as the primary objective
Maximum depth: 11,270m

A hotchpotch of motives including the engineering challenge, human exploration, science – and the publicity will come in pretty handy, too.

HOW DEEP IS YOUR SUB?



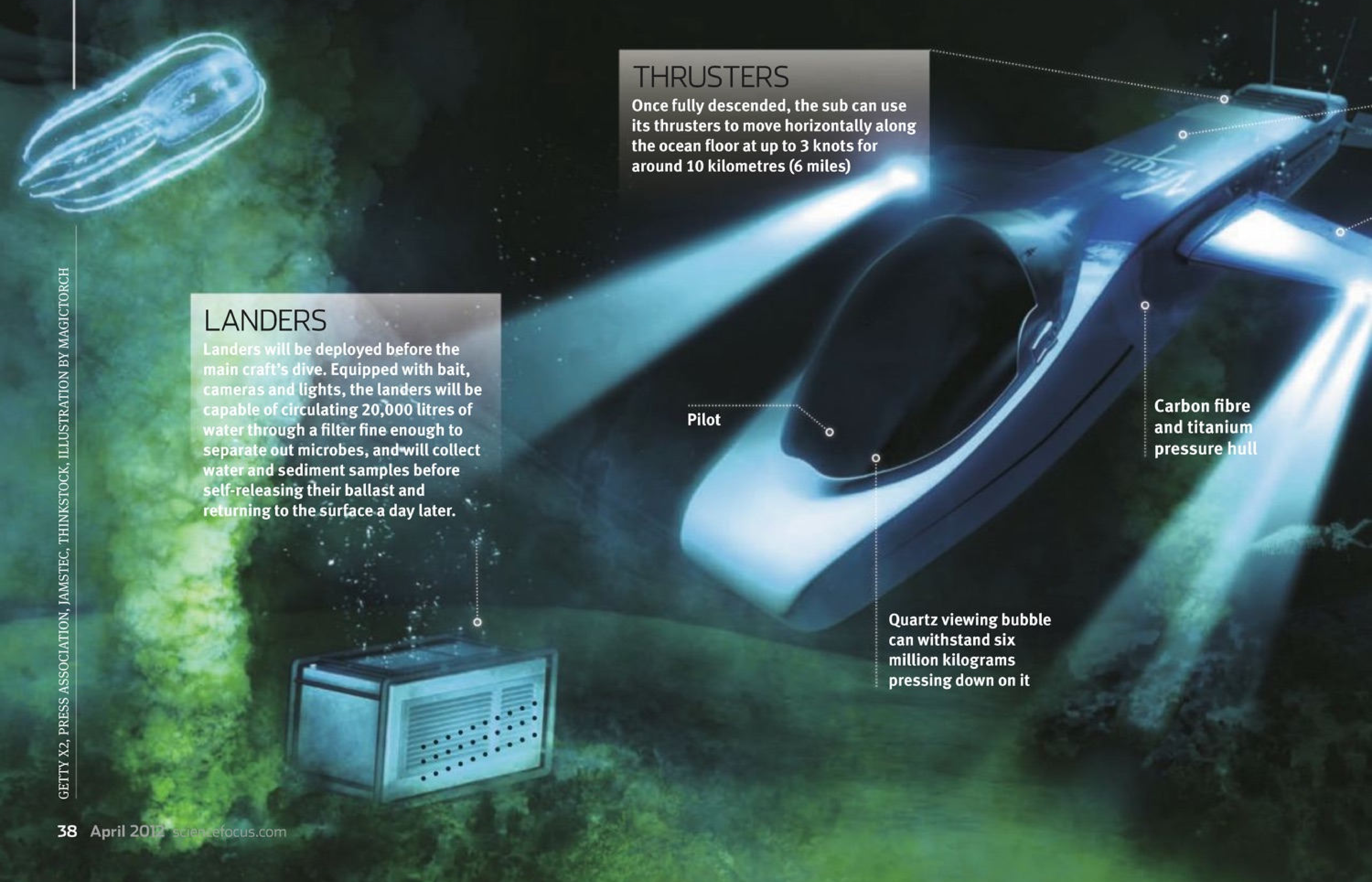
▶ was granted mineral exploration rights in the area by the International Seabed Authority (ISA), a United Nations body that oversees mining in international waters. This year Jiaolong is due to dive to 7,000m, which would see it snatch the title of 'deepest diving in-service manned submersible' from Japan's Shinkai 6500.

China appears to have no ambitions to venture into the Mariana Trench, unlike the other teams – it is focused on deep-sea mining. Last year the ISA approved applications from China and Russia to explore new deposits of polymetallic sulphides, which form near volcanic vents in seabed ridges and contain metals such as copper, lead, zinc, gold and silver. Deposits, mostly found in the Pacific so far, range from several thousand to 100 million tonnes. It is literally a gold mine under the waves. There are also known to be valuable rare earth metals, used in high-tech items such as electric vehicle batteries and wind turbines, at depths of 3,500-6,000m

China's mining exploration plans horrify a fourth group that does have its sights firmly set on the Mariana Trench. The Deepsearch project involves the design and construction of two large, advanced submersibles by Deep Ocean Exploration and Research (DOER), a company based near San Francisco. Its founder is Sylvia Earle, the renowned oceanographer affectionately known as Her Deepness, and the project has received several million dollars of research funding from Google executive chairman Eric E Schmidt.

"We just don't know what would be destroyed in the process," says DOER president Liz Taylor of China's mining plans. "The next cure for a disease could be contained in a microbe that lives at the bottom of the sea, and we are just going to rip it all up to pull out some minerals?"

While our planet's surface has been largely mined of antibiotics and other medically useful chemicals, 'Neptune's medicine chest' has not. Already microbes have been found to produce omega-3 fatty acids – chemicals which are vital for the body to function and can fight ▶



THRUSTERS

Once fully descended, the sub can use its thrusters to move horizontally along the ocean floor at up to 3 knots for around 10 kilometres (6 miles)

LANDERS

Landers will be deployed before the main craft's dive. Equipped with bait, cameras and lights, the landers will be capable of circulating 20,000 litres of water through a filter fine enough to separate out microbes, and will collect water and sediment samples before self-releasing their ballast and returning to the surface a day later.

Pilot

Carbon fibre and titanium pressure hull

Quartz viewing bubble can withstand six million kilograms pressing down on it

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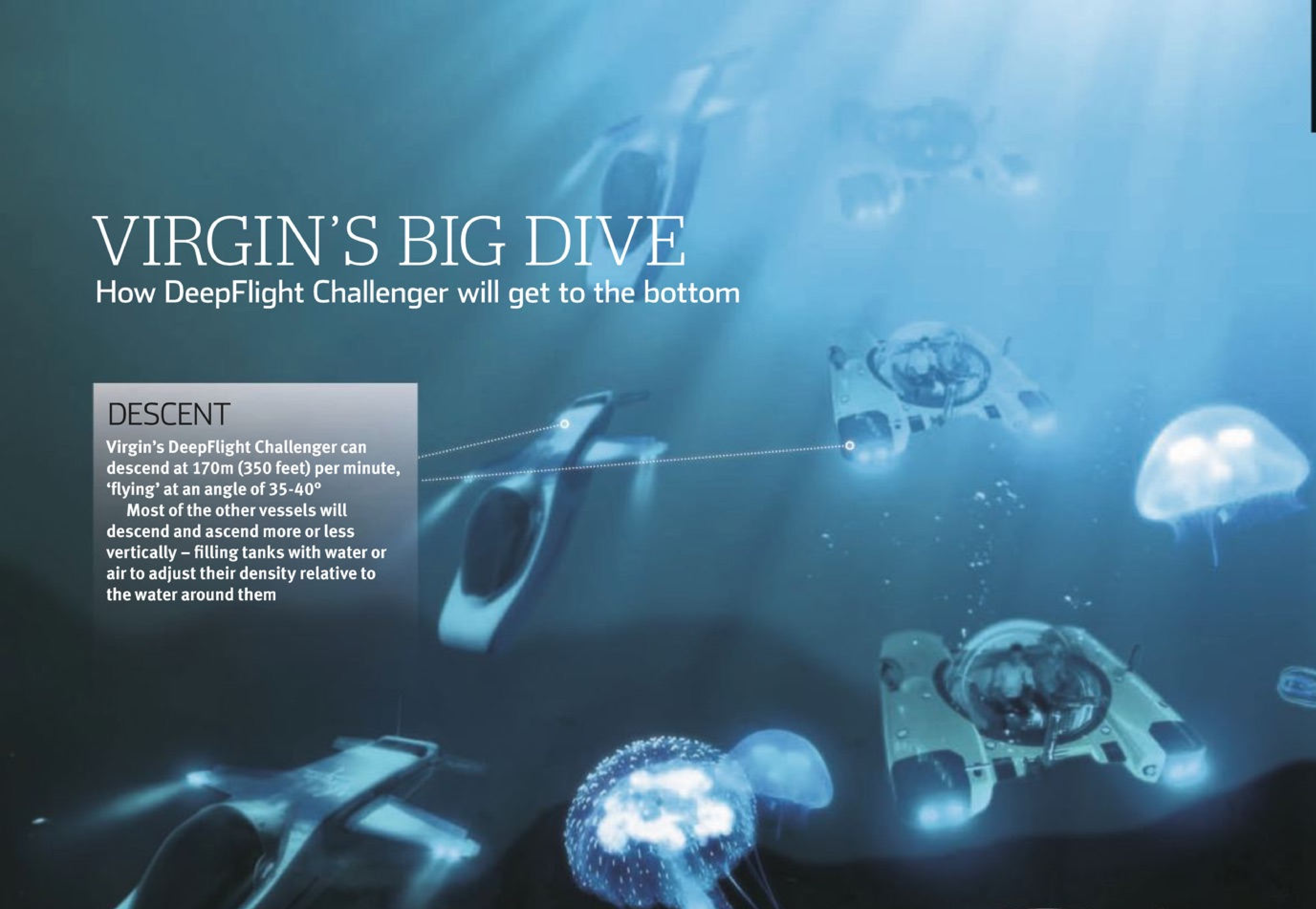
VIRGIN'S BIG DIVE

How DeepFlight Challenger will get to the bottom



DESCENT

Virgin's DeepFlight Challenger can descend at 170m (350 feet) per minute, 'flying' at an angle of 35-40°

Most of the other vessels will descend and ascend more or less vertically – filling tanks with water or air to adjust their density relative to the water around them

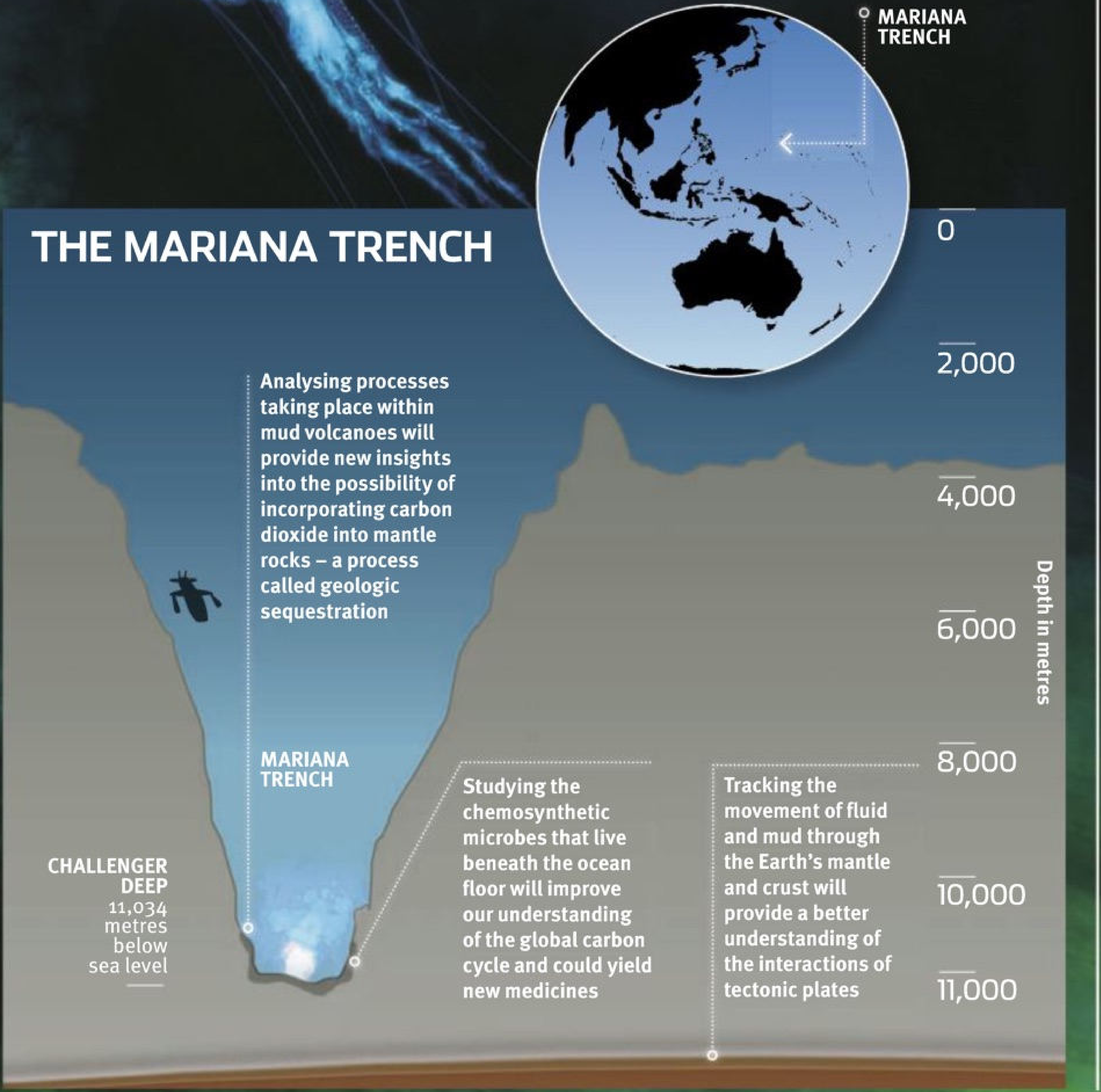
Flotation tank

HYDROPLANES

Hydroplanes have curved lower surfaces and straight upper ones, the opposite of aeroplane wings. This means there is greater pressure on the wing's upper surface than the lower one, allowing the craft to descend

Changeable wing-mounted pods for sonar recordings and science data collection. Will also carry ultra high-resolution cameras generating 3D and IMAX images

THE MARIANA TRENCH



CHALLENGER DEEP
11,034 metres below sea level

Analysing processes taking place within mud volcanoes will provide new insights into the possibility of incorporating carbon dioxide into mantle rocks – a process called geologic sequestration

Studying the chemosynthetic microbes that live beneath the ocean floor will improve our understanding of the global carbon cycle and could yield new medicines

Tracking the movement of fluid and mud through the Earth's mantle and crust will provide a better understanding of the interactions of tectonic plates

Deep ocean scientist

Prof Katrina Edwards is a member of the Virgin Oceanic team and an expert on the 'deep biosphere' – the life that lurks underneath the ocean floor

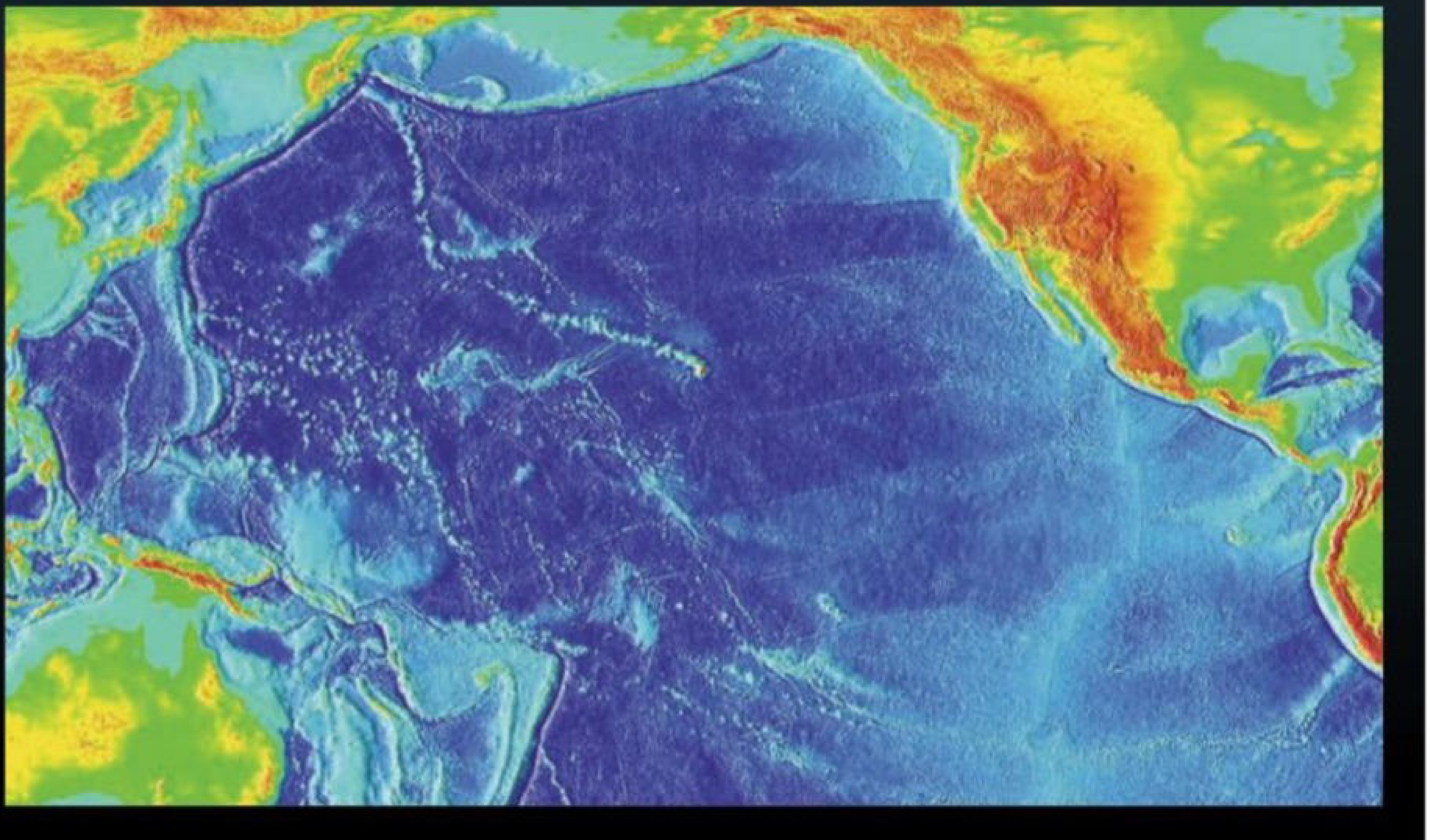
Are there still new environments to study beneath the ocean surfaces?
We know something about the life forms that exist in the deep sea in proximity to hydrothermal vents and mid-ocean ridges, but not much about trench environments. Our understanding of the surfaces of other planets in the Solar System is greater than our understanding of the ocean floor.

What do you want to study down there?
We want to find out more about the microbes that live beneath the ocean floor. They use chemicals in the Earth's crust, rather than light, as a source of energy. They produce carbohydrates chemosynthetically rather than through photosynthesis. Satellite imagery shows us how much carbon is produced by photosynthesis, but this does not pick up any of this chemosynthesis going on in the dark. So this work will provide a better understanding of the carbon cycle as a whole.

How much is already known about chemosynthetic microbes?
Very little at present. There is some evidence that they play an important role in establishing the base of the food web – the complex of interrelated food chains – in the deep ocean. However, we are really only at the beginning of our understanding about how important that is. As much iron is released from the rock in this sub-seafloor world as is delivered to the oceans from all the rivers in the world. It may be microbes that are responsible for getting the iron – and other substances – out of the rock into the ocean.

Is this research likely to have wider scientific applications?
The technology needed to do this kind of science has multiple spin-offs. We used a specially developed probe to scan for microbial life in bore holes during a recent expedition in the mid-Atlantic. That could now be used in the food industry to look for microbes. There is also always the possibility of discovering new organisms with new enzymes that could be useful in biotechnology and medicine.

Why do you need a manned vessel?
So far we have not been able to reproduce the human brain in a computer. Humans can take in information, process it right there and react to what they have discovered in real time, in ways that a robot can't.



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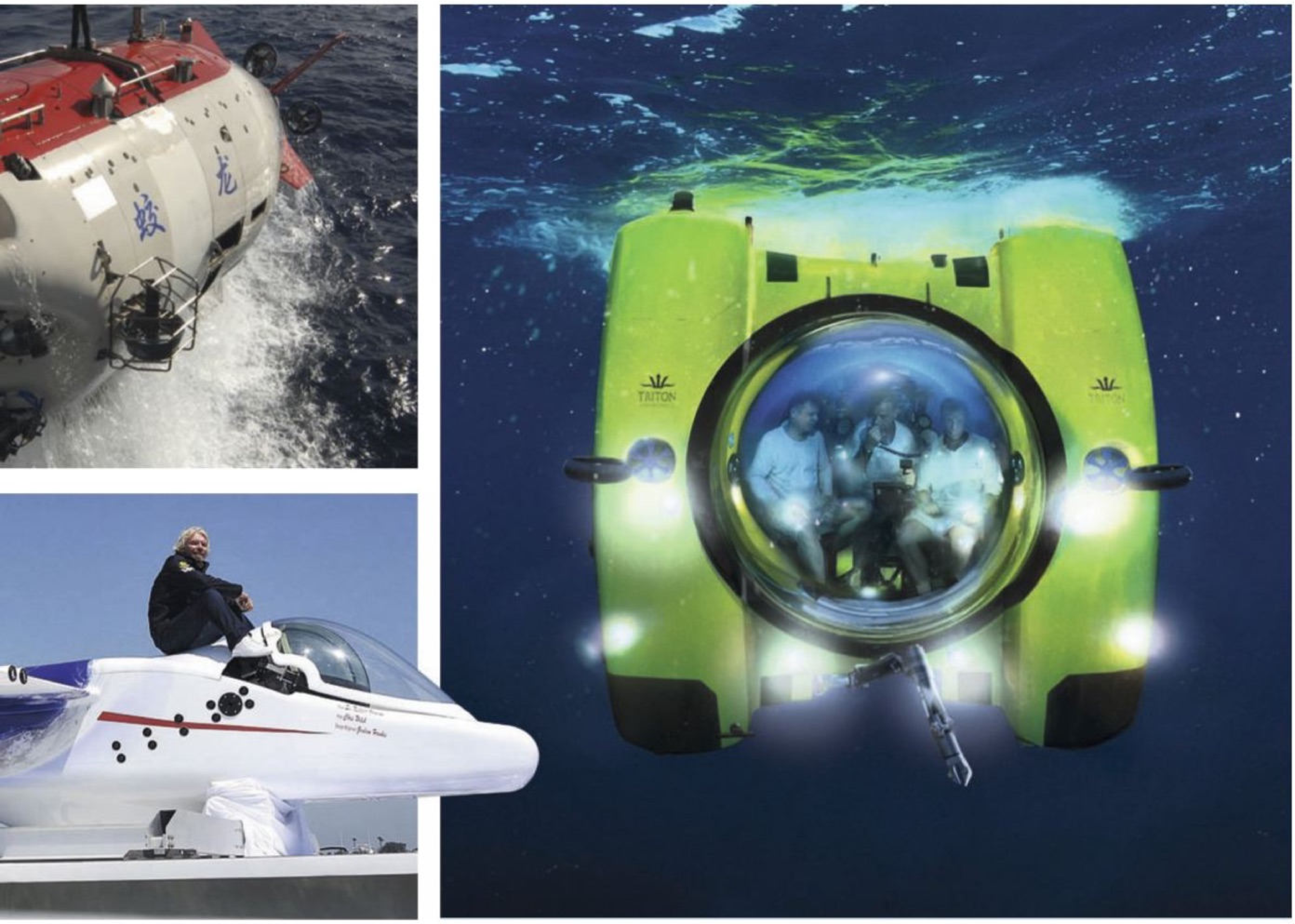
▶ cancer and cardiovascular disease. Bacteria that lurk in deep-sea sludge have been found to produce a chemical called SalA, which is already being tested on volunteer cancer patients to treat blood and bone cancers. Despite these early successes, however, the deep-sea environment remains a largely untapped resource.

As part of the Virgin Oceanic project, scientists at Scripps Institution of Oceanography near San Diego will make use of autonomous landers to gather samples of water and bottom sediment. These will be



Clockwise from top left: Jiaolong, Triton 36000/3, DeepFlight Challenger

filtered to concentrate viruses and other types of microbe. It is believed likely that many new species will be discovered, that could yield a whole host of new enzymes and genes.

New life forms

Perhaps even more exciting would be the discovery of new species of vertebrate. After all, Walsh and Piccard, the pilots of the *Trieste*, have already provided a tantalising glimpse of the life that can survive at the bottom of Challenger Deep – almost seven miles beneath the surface, where there is no light and the pressure is roughly 1,100 times that on the surface. That's the equivalent of a family car pressing down on each square centimetre.

Walsh and Piccard also inadvertently left behind their own research project – they released two tonnes of iron pellets at the bottom of Challenger Deep to allow their three-hour ascent to the surface to begin.

"I will be highly surprised if we don't find microbes that consume iron," says Dr Katrina Edwards, a biologist at the University of Southern California, who is a member of the Virgin Oceanic science team. "We might also discover novel enzymes and processes that could have a practical benefit to society."

The potential impact of these deep-sea creatures on our lives must not be underestimated, says Professor Douglas Bartlett at Scripps Institution of Oceanography, another member of the Virgin team. "Given that the physical conditions for life in a deep-sea trench have more in common with Jupiter's moon Europa than the surface of our planet, it would not be surprising if some new chemicals with biomedical applications are also present at depth," he says. "We ▶

▶ know next to nothing about this environment, except that this is one alien setting where life flourishes."

Aside from medicine, these deep-sea microbes may have other practical benefits. There is already research looking at harnessing microbes that inhabit deep-sea trenches to degrade plastic, while some deep ocean microbes are proving adept at cleaning up oil spills.

Underwater fireworks

Even before the crews reach the bottom of the ocean, there will be some interesting science to be done. We know why many creatures produce their brilliant flashes of colour. The scaleless dragonfish, for instance, uses red bioluminescence – invisible to most animals at depth – like an infrared sniper scope to illuminate its unsuspecting next meal. In some species though, it's not clear why they might devote valuable resources to bioluminescence and the Virgin Oceanic team hopes the missions will shed new light on this. Their research will also help to determine whether bioluminescence can be used to uncover the distribution of animals and monitor the health of different marine ecosystems.

So while descending to the deepest depths is all about fame, glory and riches for some teams, it's likely that the greatest long-term rewards will come in the form of ground-breaking science and novel technologies. "The most important prize is knowledge, and the sharing of technology and data," says DOER president Taylor.

Science aside, who is going to reach the finish line – the floor of the Mariana Trench – first? Last year, Cameron predicted it would be the Virgin team. However Virgin's cracked viewing screen has set it back a year. Triton founder Jones, who has discussed their respective projects with Cameron, is confident he knows who the smart money should be on.

"I think there's no question that Cameron will be first," says Jones. "His vehicle is very close to being ready." So whatever is lurking at the bottom of the ocean, we could all soon be coming face to face with it on a cinema screen. ■

Nic Fleming is a freelance science writer based in London

FIND OUT MORE

bit.ly/bioluminescence
Incredible footage of bioluminescence

bit.ly/sylviaearletalk
TED talk on preserving the oceans by Sylvia Earle

Atlas Of Oceans
John Farndon (Thomas Reed, 2011)

j.mp/xMUqwF
Listen to a Radio 4 documentary entitled *Oceans: What Lies Beneath*

j.mp/xIM5uS
Melvyn Bragg explores the deep in a Radio 4 *In Our Time* programme

http://j.mp/yRL2IT
Costing The Earth: Deep Sea Treasure is another documentary from Radio 4

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SO YOU WANT TO BE A SCIENTIST?

Kieron Allen speaks to the participants in Radio 4's science contest to find out how a group of amateurs will be looking for answers to some burning questions

Have you ever fancied conducting your own scientific experiment? If so, tune in to BBC Radio 4's *Material World*, where each year, *So You Want To Be A Scientist* gives four listeners the opportunity to test their theories in a scientific setting. They'll work with experts who will mentor them through the time-honoured process of method, results, conclusion. All four will present their findings at the Cheltenham Science Festival in June, and a panel of judges will select an overall winner. Last year's winning entry examined the 'homing' distance of garden snails – read on to find out what 2012 has in store.

NAME: ISABEL THOMLINSON
AGE: 17
SCIENCE BACKGROUND:
STUDYING A-LEVEL CHEMISTRY, PHYSICS AND BIOLOGY

WHY DO PEOPLE FIND CERTAIN NOISES UNBEARABLE?

"The idea came from an observation I had made about how some people find certain noises, such as nails on a blackboard, very unpleasant while others don't mind them. I thought it was a bit weird. I've always been interested in science: I'm doing science A-levels at the moment and I hope to take chemistry at university next year. I think the competition is a really good chance to get into real science, and of course to carry out an experiment with Trevor Cox is a great opportunity."

MENTOR: **PROF TREVOR COX**

"I think it's a great idea. There's a mystery around the fact that some people react so strongly to these noises and we don't really know why. So it's a great scientific mystery to try and unravel. Her original idea has been looked at a few times before, so it would be nice to come up with something new. There's an area of study called noise sensitivity that's normally applied to things like how disturbed you are by environmental or traffic noise. We could apply it to this"

Find out more: http://on.fb.me/w6A4ms

NAME: VAL WATHAM
AGE: 53
SCIENCE BACKGROUND:
PSYCHOLOGY DEGREE

WHAT EFFECT DOES THE DESIGN OF FABRIC HAVE ON OUR PERCEPTION OF SOMEONE'S SIZE?

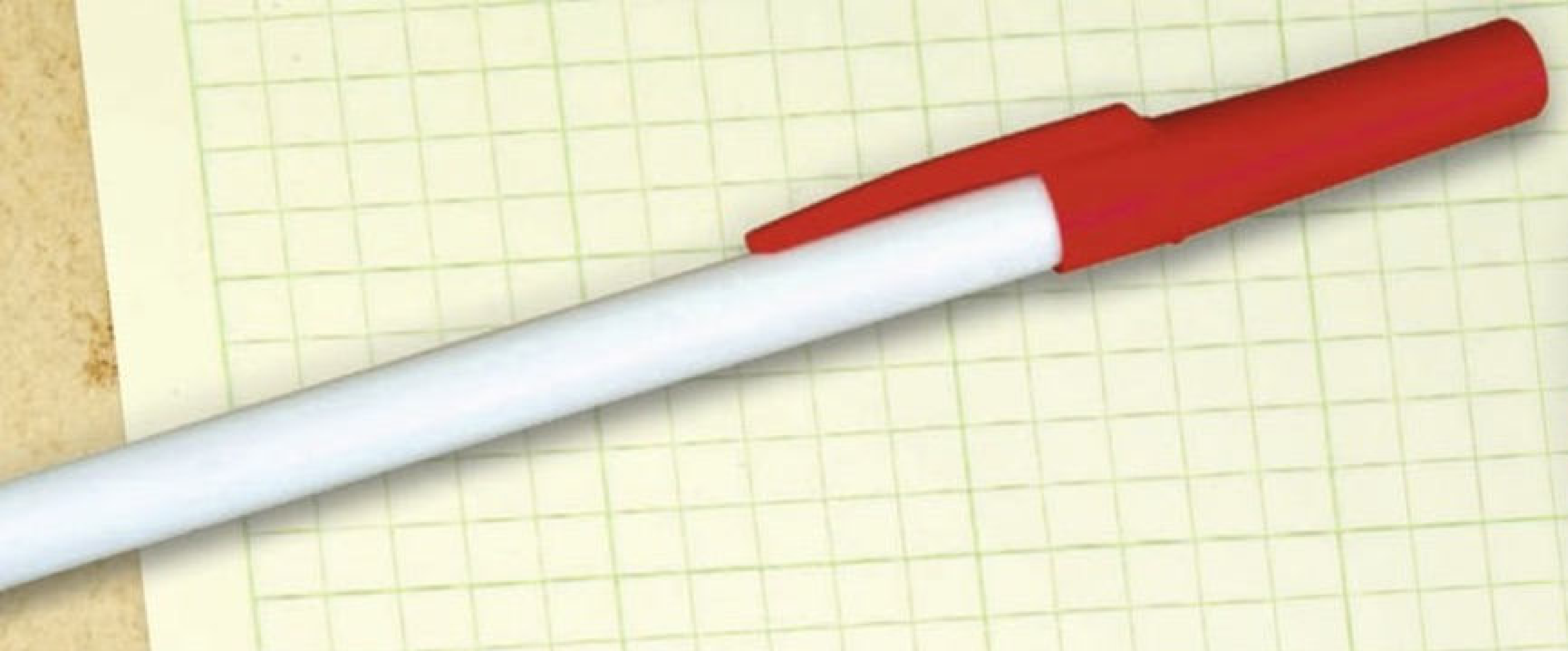
"The idea was triggered by the work that Peter Thompson did a year or two ago. The idea that horizontal stripes were more flattering got quite a lot coverage in the media, and of course the press said, 'Oh, it's not vertical stripes as we thought'. But when I looked at the pictures I thought, 'Well, it's all 2D: it's pictures, and that's not very real.' It seemed to me that there was a big gap between what you would see in two dimensions and what you would see in real life, talking to someone and watching them move."

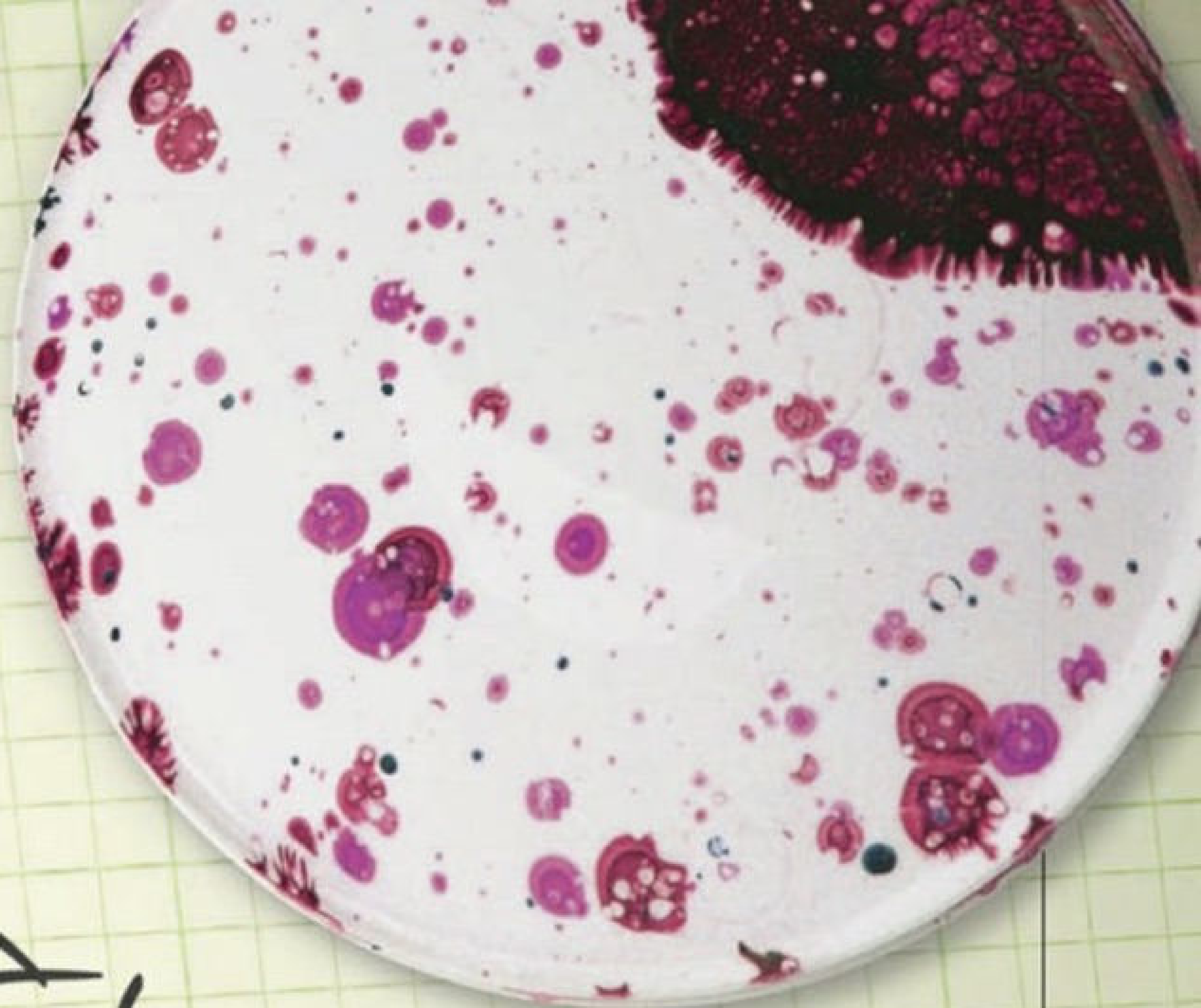
MENTOR: **DR PETER THOMPSON**

"This is an experiment I wanted to do myself but I had been inhibited from doing so because I thought it was too tricky. It's quite difficult to think of the metric you're going to use: what are you going to measure? There's a danger that people will come with preconceptions about what clothes can do – a very obvious example of this might be, 'horizontal stripes make you look fat'. We want a measure that is free from these biases."

Find out more: http://on.fb.me/zxrCP7

THINKSTOCK X7





NAME: DARA DJAVAN KHOSHDEL
AGE: 24
SCIENCE BACKGROUND: ENROLLED ON AN ACCESS TO SCIENCE COURSE

CAN THE VALUE OF A PAINTING BE PREDICTED FROM THE EMOTIONAL RESPONSE OF PEOPLE WHO VIEW IT?

"I first got the idea from a book called *The Tell-Tale Brain* by VS Ramachandran. It talked a lot about neuroesthetics but it was really speculative, and I came up with an idea to test the kind of theories it talked about. Art doesn't do much for me but it seems to do a lot for others, so I wanted to look into that. Right now we're just at the beginning. I've met my mentors, and we've just started dialogue via email as to how the experiment might pan out."

MENTORS:

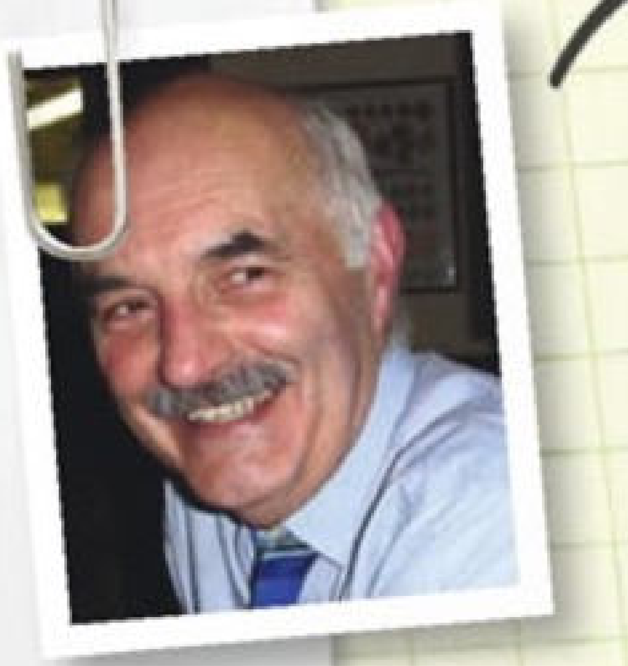
PROF ANDREW PARKER

"Dara's idea has an ingenious directness: is the value of art intrinsically linked to its financial value? It's a slightly reductionist approach, but worth looking at."

PROF MARTIN KEMP

"Dara and I are both keen on testing people's reactions in a naturalistic context, like a gallery. Lying in an MRI scanner in a lab bears no relation to the messy, contextual way we experience art."

Find out more: http://on.fb.me/zHazZo



NAME: WILLIAM RUDLING
AGE: 69
SCIENCE BACKGROUND: GCE SCIENCE

IS THERE A LINK BETWEEN THE SHAPE OF A PERSON'S FACE AND THE SOUND OF THEIR VOICE?

"The idea came out of my work as an illustrator. I sometimes do caricatures and it struck me that often, unrelated people who had similar faces had similar voices too. The revelation for me was seeing Judi Dench and Samantha Bond together: there's a real connection between them. Jools Holland and actor Danny Webb are very similar as well. It's amazing to be involved with the competition. I'm looking forward to working with my mentor, who I'm sure will prove invaluable as we progress things from a research point of view."

MENTOR: **DR PAUL CARTER**

"This will appeal to a lot of people because it's the sort of thing we notice. For instance, people have often heard someone on the radio and then found out they look nothing like they thought they would. There are things such as regional accents that influence the way people sound, but this experiment says, 'Let's take away these social factors and be left with things that reflect purely physical characteristics'."

Find out more: http://on.fb.me/zDuWy7

Peter Thompson
Doctor of Psychology at the University of York
Specialism: Perception of motion and speed

Trevor Cox
Professor of Acoustic Engineering at the University of Salford
Specialism: Surface diffusion

Martin Kemp
Emeritus Professor of the History of Art at the University of Oxford
Specialism: Imagery in art and science

Andrew Parker
Professor of Physiology at the University of Oxford
Specialism: Neural activity and perception

Paul Carter
Postdoctoral Research Fellow at the University of Leeds
Specialism: Phonology and linguistics

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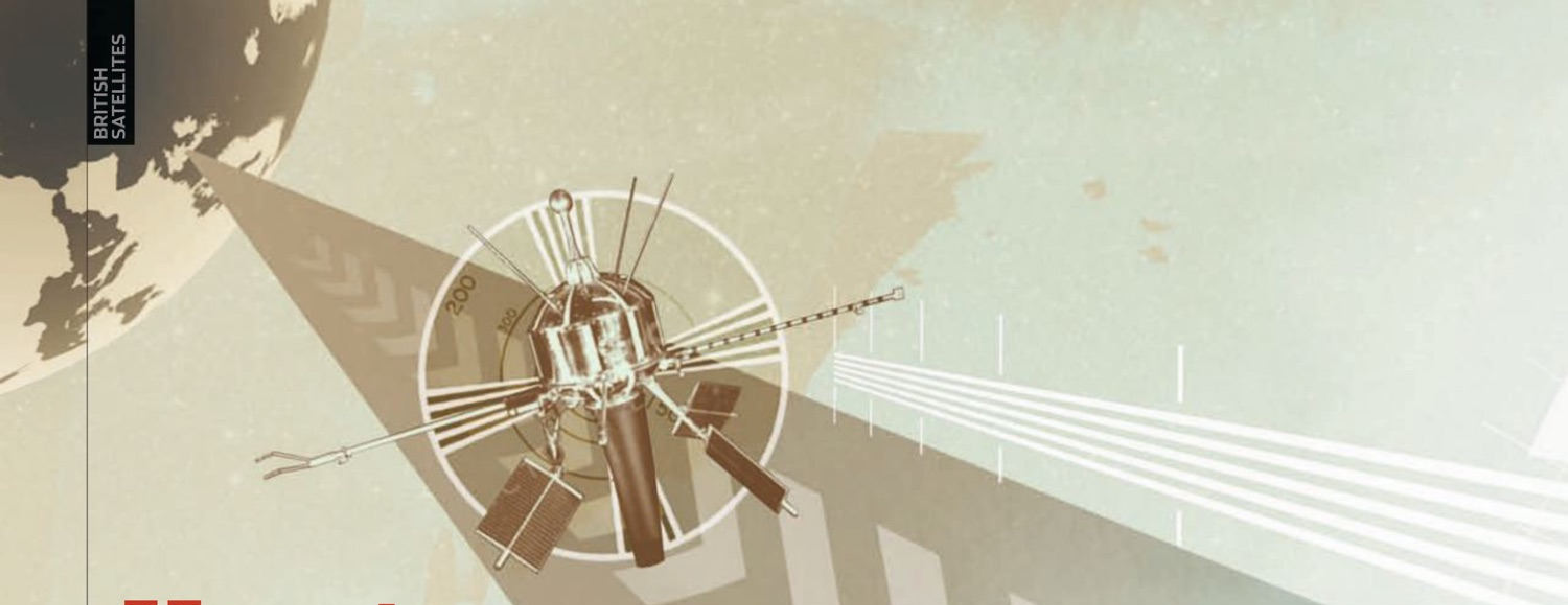


How to build a satellite

Half a century on from the launch of Britain's first satellite, **Sean Blair** takes a look at how the latest 'comsats' are built, and finds that a lot has changed in 50 years...

Half a century ago this month, Great Britain took its first small step into space. On 26 April 1962 a gold-coloured object resembling a barbecue grill was shot into an elliptical orbit around Earth. While the body of Ariel-1 was built by NASA, the satellite was packed with seven experiments designed at UK universities. To many, it represents the first British satellite.

Ariel-1 was a key step in the formation of a UK space industry that today generates £7bn annually and provides over 70,000 jobs. Previous British experiments had made it out of the atmosphere, but only briefly, as passengers aboard Skylark suborbital rockets launched from Woomera, South Australia from 1957 onwards. Some of these early experiments were crude, such as one that involved filming exploding hand grenades to estimate high-altitude conditions. But they gave UK research teams experience in designing for space.

"There were plenty of first class scientists dabbling at the edge of space. So we had the skills ready when NASA began to invite partnerships," says Doug Millard, space curator at London's Science Museum.

To build Ariel-1, an equal partnership between Britain and the US was forged. A Telex line was set up between NASA's Goddard Space Flight Center in Maryland and University College London, so that satellite and payload development could be coordinated. The Americans had just as much to gain as the British – UK scientists had been researching the ionosphere, the atmosphere's electrically charged upper layers, for decades. The question was how it might affect spacecraft – and indeed missiles – as they hurtled through it.

Some 50 years on, Britain has become an important hub for satellite building, employing materials and techniques vastly different from those seen on Ariel-1.

At aerospace giant Astrium's Stevenage facility stand six-tonne Eurostar 3000 communication satellites, towering like upended Transit vans. They're in various stages of development, but all are destined for the 'Clarke Belt'. In 1945, young RAF officer Arthur C Clarke, his science-fiction still ahead of him, suggested placing communications relay satellites 36,000km (22,400 miles) up, where their orbit would keep them fixed relative to Earth's surface. Clarke's idea inspired a thriving geostationary communication ▶

ILLUSTRATION BY ANDY POTTS

THEN AND NOW

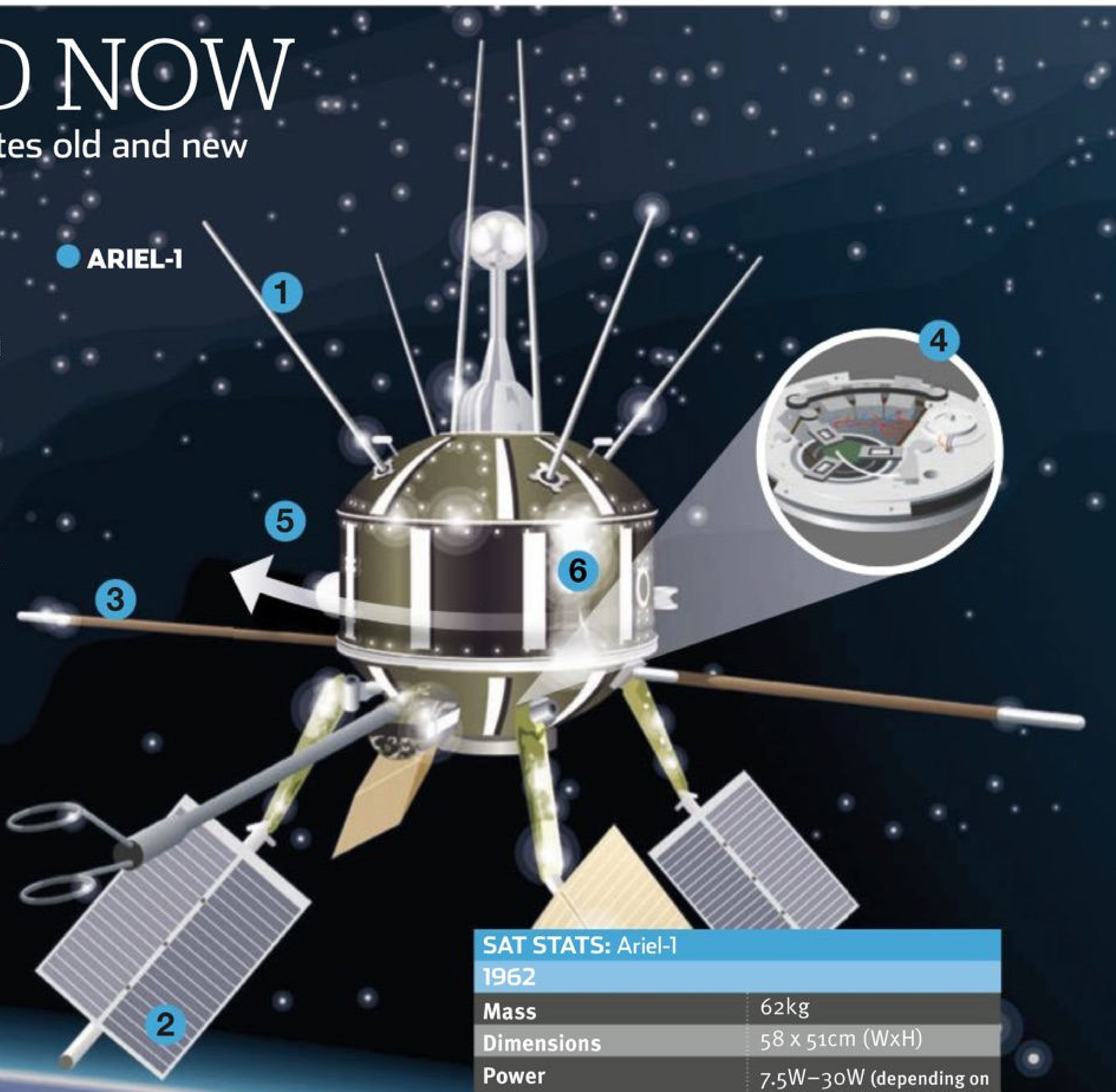
A guided tour of British satellites old and new

Radio antennas ①, solar arrays ② and inertia booms ③ (to control the craft's spin) extended out from Ariel-1. A Eurostar 3000 can have a 'wingspan' up to 35-45m long ①. Its arrays unfold once the craft reaches its orbit, as do multiple 2.5m antennas ② to receive and transmit signals.

On Ariel-1, experimental results were recorded on a 100-minute tape ④, long enough to store a single orbit's worth of data before it was 'dumped' to a ground station. A Eurostar 3000 can incorporate up to 90 separate transponders ③ to process, amplify and re-transmit TV, telephone or data signals.

Ariel-1 span at around 50rpm to stop it from tumbling out of control ⑤. Modern telecommunication satellites fire thrusters ④ to maintain Eurostar 3000's orientation whenever the onboard gyroscopes detect that a correction is needed.

To protect Ariel-1 against the extreme temperatures of space, first copper and then gold were buffed to a mirror finish on the surface ⑥. Each Eurostar 3000 is wrapped in multi-layer insulation ⑤, its panels threaded through with internal heat pipes filled with ammonia which evaporates, cooling the satellite. The ammonia is then recondensed and recirculated.



SAT STATS: Ariel-1	
1962	
Mass	62kg
Dimensions	58 x 51cm (WxH)
Power	7.5W–30W (depending on solar panels' attitude to Sun)
Onboard data handling	100min, tape recorder
Design lifetime	1 year

▶ satellite or 'comsat' industry, with Britain commanding a sizeable share of the market.

Satellites today

In the same way that Ariel-1's structure was built in the US and its instruments were built in the UK, modern satellites are divided into two halves – the service module contains propulsion and other key subsystems, while the payload module does the work. Once Astrium's Stevenage plant completes the payload module, it is kitted out with electronics at the company's facility in Portsmouth while Stevenage finishes the service module. The two segments are then put together and tested at Astrium's plant in Toulouse, France.

Work gets done within a set of vast 'cleanrooms' at these sites, in which air is dehumidified, temperature-controlled and regularly passed through microscopic filters to stop any dust reaching delicate satellite systems. These chambers are kept slightly pressurised to prevent the external atmosphere leaking in. The walls are vinyl-covered to prevent flaking plaster, while the floors are earthed to guard against static.

Engineers enter the cleanrooms through an airlock in protective suits. These stop their bodies shedding their typical 100,000-plus particles of skin and hair a minute, which goes up to five million particles a minute when walking. Running is a no-no,

The solar arrays of these power-hungry comsats are their only moving parts

SATELLITE SUCCESSES

The rise and rise of British satellites

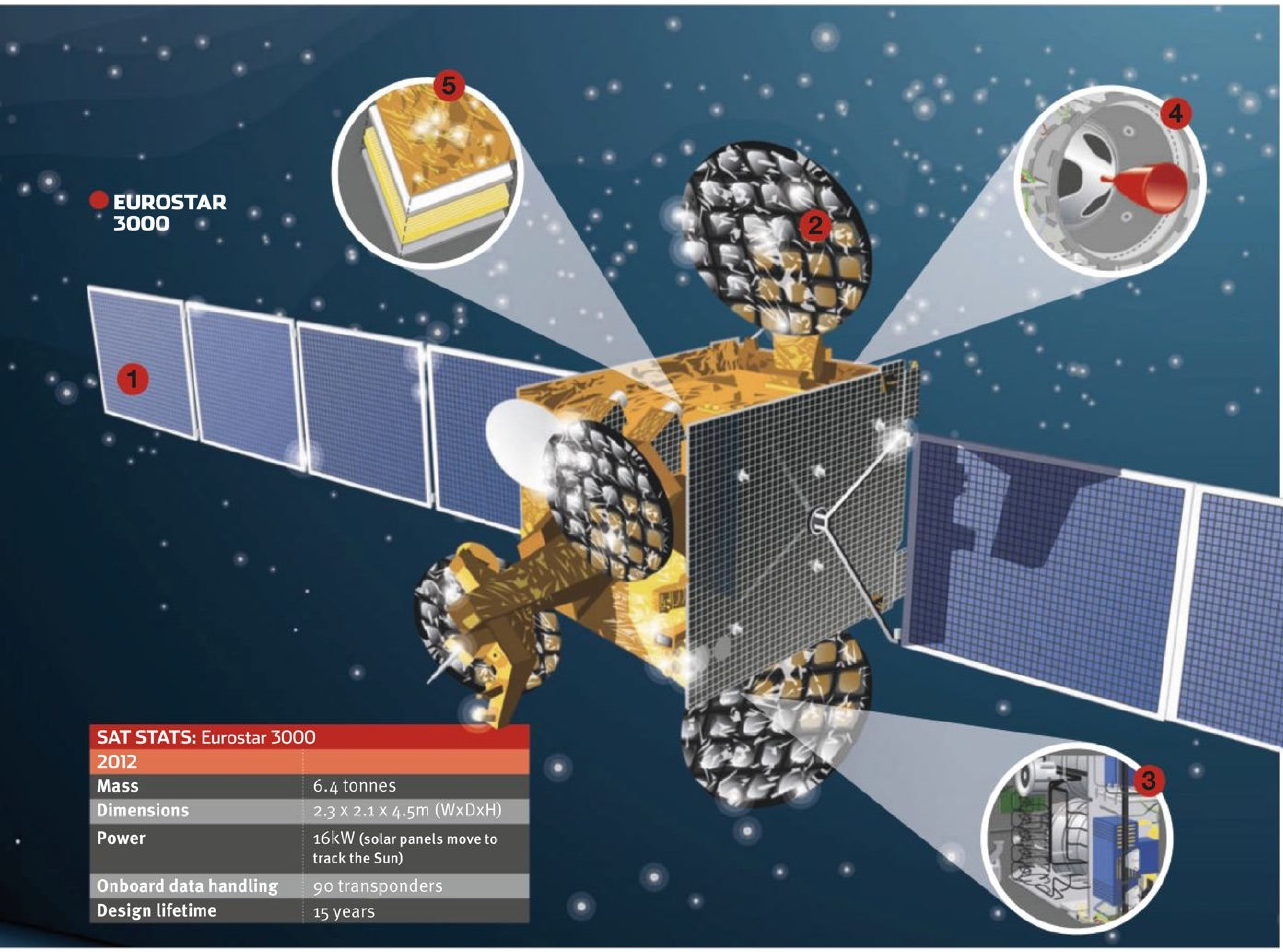
1962

Ariel-1 lifts off from Cape Canaveral on a Thor-Delta rocket, carrying British scientific payloads. Among the Ariel missions that follow is Ariel-3 in 1967, the first fully UK-built satellite.

1971

Prospero-1 is launched on a British rocket, Black Arrow, from South Australia, making Britain the sixth nation to place a satellite in space. The satellite incorporates a micrometeoroid detector.

ESA, SURREY SATELLITE TECHNOLOGY, NASA, ILLUSTRATION BY PAUL WESTON



SAT STATS: Eurostar 3000	
2012	
Mass	6.4 tonnes
Dimensions	2.3 x 2.1 x 4.5m (WxDxH)
Power	16kW (solar panels move to track the Sun)
Onboard data handling	90 transponders
Design lifetime	15 years

and so is strong aftershave which could condense on optical gear, diminishing its accuracy. Cosmetics are off limits too, because of the risk of contaminating sensitive instruments.

A similar approach was employed during Ariel-1's manufacture, albeit a little less rigorously. Ariel-1's 520 transistors and other components were less sensitive to contamination than today's microprocessors, which can incorporate millions of transistors on a single chip.

Antenna dishes for Astrium's satellites are manufactured on-site from carbon-fibre composites, their shape subtly distorted to maximise signal coverage over regions of the customer's choice. They stay lined up because geostationary satellites maintain a fixed position and orientation, using thrusters to fine-tune their position. The solar arrays of these power-hungry comsats are their only moving parts, continuously tracking the moving Sun. "We test the drive mechanisms for the equivalent of 35 years, to guarantee they'll work for 15," says Bob Graham, Head of Engineering at Astrium UK.

In a spin

Ariel-1 was prevented from tumbling out of control by spinning like a top. This spin was initiated by the final stage of the Thor-Delta rocket on which it was launched, which itself rotated. The satellite's 'spin-stabilised' nature dictated the use of ▶

1974

The MoD's Skynet 2B satellite is launched into geostationary orbit over the Indian Ocean. It is the first communications satellite in space from outside the US and USSR, having been built in Portsmouth.

1981

The first 'talking satellite', UoSAT-1, is launched on a Delta rocket. Built at the University of Surrey, the craft sends back telemetry data, such as the amount of power generated by its solar cells.

1985

ESA's first deep space mission, the Giotto probe to Halley's Comet built by British Aerospace, is launched by Ariane 1 from French Guiana. It returns the first close-up glimpse of a comet's nucleus.

▸ non-ferrous building materials, to avoid any magnetic field affecting its rotation. Accordingly, it was assembled from an aluminium body, covered with a fibreglass skin.

Astrium's Eurostar comsats need to be strong but light, so their two-storey structures are formed from a woven carbon-fibre core – similar to those in F1 cars – around which honeycombed aluminium panels are fitted. Different sides of the comsats can be exposed to vastly different temperatures, with one side always facing the Sun and the other always facing Earth.

"The environment in space causes thermal distortions and misalignments, so we add thermal blankets, heaters and heat pipes," says Graham. These distribute the heat around the craft. Fitting this insulating layer around the satellite is an exercise in precision. "It's like Savile Row tailoring. We make a pattern and then stitch the insulation together to fit," says Graham.

Ariel-1 received more basic protection from the space environment, with layers of paint, copper, lacquer and a microscopic sputtering of gold – but then it was spinning, so the heat was more evenly distributed. Astrium comsats also boast more than a touch of bling. Some 20kg of gold wire is employed per mission as the ideal non-corrosive, strongly conductive material.

Testing, testing...

Down in Portsmouth, the Eurostar's communications module is tested in a radio-absorbing chamber to mimic infinite space. Crosstalk between the myriad of signals handled by the satellite is a big risk. So the output of signals, which may be different TV channels, is synchronised using the purest quartz crystals in the world. These crystals are specially grown at a dedicated Stevenage lab. Quartz oscillates at a regular frequency when electrically charged, and it is this oscillation that is used to coordinate the signals' timing.

"The accuracy we require is equivalent to laying a trail of sand from London to New York, then knowing if a grain of sand has been removed," says Graham. "Commercial quartz isn't pure enough – it would turn black under exposure to space radiation, affecting its vibration."

Ariel-1 emitted only one signal, so signal coordination was not an issue. But radiation exposure turned out to be: on 9 July 1962, the US tested a nuclear weapon at an altitude of 400km (250 miles), saturating Ariel-1's instruments and degrading its solar panels. The mission was effectively crippled, but Ariel-1 managed to limp on until November 1964, when it was turned off. It re-entered Earth's atmosphere in 1976.

About 40 per cent of the world's telecom satellites are made in the UK

Small is beautiful

That early satellite might be dwarfed by the largest of its modern descendants, but evolution doesn't always equal increased bulk. Surrey Satellite Technology Ltd (SSTL) in Guildford, Surrey, has become a world leader in small satellites. It's launched 36 spacecraft including a fleet of dishwasher-sized Disaster Monitoring Constellation satellites for Earth observation. The Astrium-owned company is currently working on a similarly sized mission called

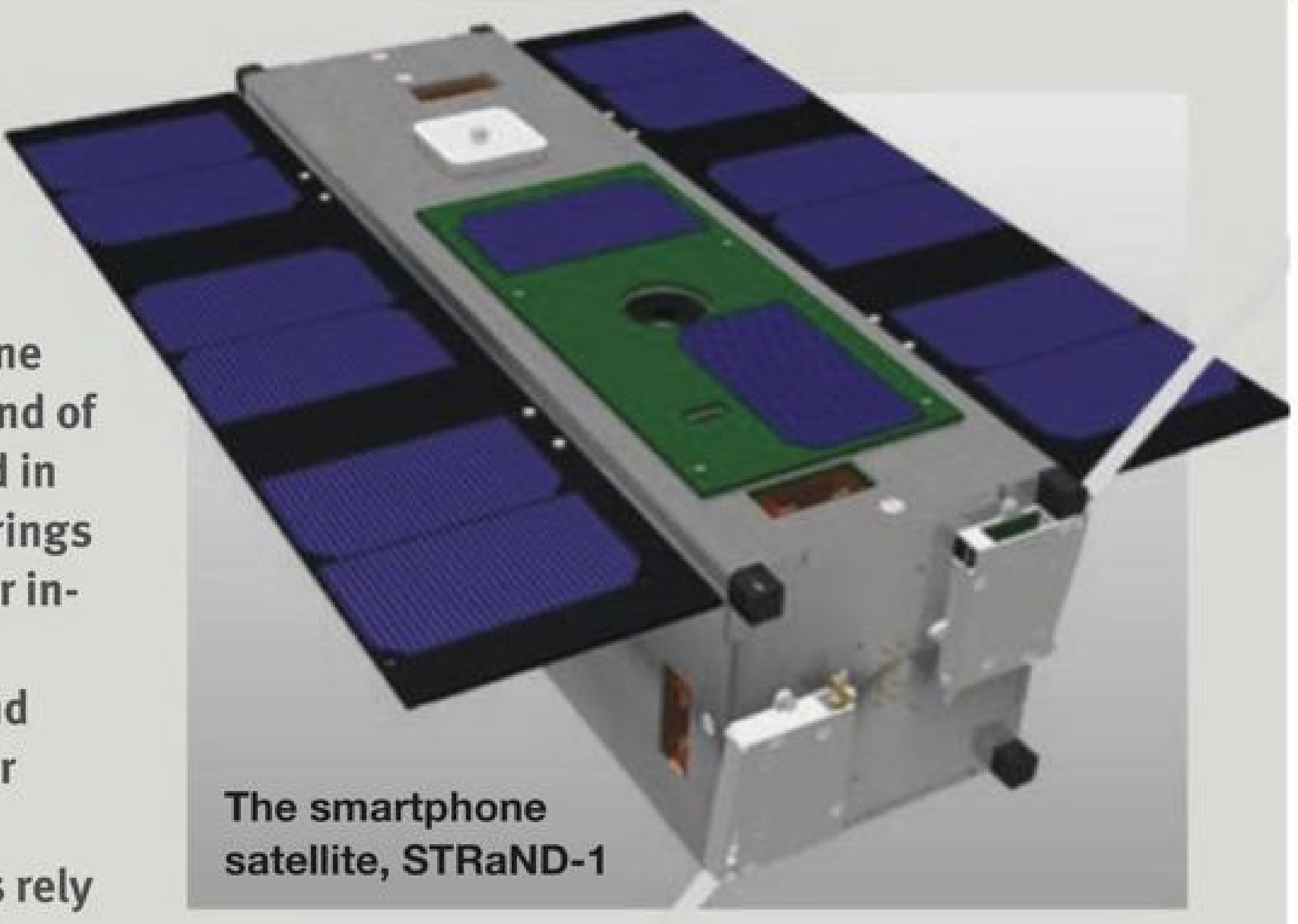
FROM SUBURBIA TO SPACE

Technology that's finding its way onto today's British satellites can be found in and around your house

Smartphones, Nintendo Wiis and satellites have something in common – a reliance on gyroscopes to measure their motion. Traditionally, satellites have used full-sized spinning discs, but these are prone to fail. Instead, interest is shifting to the kind of micro-electromechanical gyroscopes found in consumer electronics. These are vibrating rings etched into silicon chips, first developed for in-car electronic stability control systems.

Many of today's cars also feature GPS and it's a tool that's becoming indispensable for satellite operations, too. Surrey Satellite Technology Limited's (SSTL) DMC satellites rely on GPS to allow them to determine where they are in orbit in relation to Earth. This allows them to switch on imaging gear at the right moment.

Perhaps the most direct demonstration of the utility of terrestrial technology in space will be STRaND-1, the 'smartphone satellite'. Developed by the University of Surrey and SSTL, it incorporates a standard Google Nexus One Android smartphone whose accelerometers and GPS receivers are the heart of the guidance system. Among the apps selected to feature on the phone is one called Scream In Space, which will test out classic science-fiction film *Alien*'s famous slogan: "In space no-one can hear you scream". It will play YouTube videos of people screaming as an external mic listens in. SSTL hopes STRaND-1 will be launched later this year.



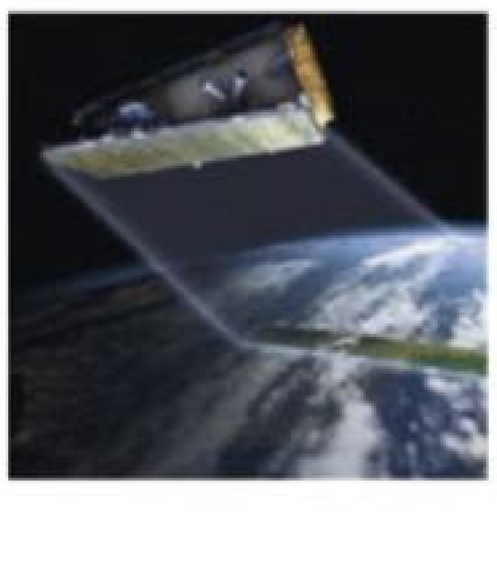
The smartphone satellite, STRaND-1

SATELLITE SUCCESSES

The rise and rise of British satellites

1990

Inmarsat-2 F1 is launched on a US Delta rocket. The first telecom satellite designed by British Aerospace and Matra Marconi Space (which have since merged as Astrium), it remains operational to this day.



2013

The first demo satellite in the NovaSAR constellation could be launched. NovaSAR will consist of four Earth observation satellites which will monitor everything from shipping to deforestation.

M DE LA NOUGEREDE/UCL/MSSL X3, ASTRIUM, SURREY SATELLITE TECHNOLOGY

TechDemoSat, flight-testing a range of UK-built technologies.

Other UK satellites are even smaller. The 10x10x10cm CubeSat standard is growing in popularity, and can be flown either singly, or doubled or tripled up. Modern CubeSats offer an Ariel-1 level of functionality at a far lower cost, making it feasible for companies and university departments to fly their own missions.

A prime example is TwinSat. In this proposed mission, a CubeSat would be packed with technology developed at University College London (UCL), and work in conjunction with a larger Russian equivalent to help detect earthquakes. "The two spacecraft will map disturbances in the ionosphere that are known to occur in the hours and days before 'quakes occur," says Professor Alan Smith, director of UCL's Mullard Space Science Laboratory. "The link is already established but we're not sure how it works – yet."

From humble beginnings with Ariel-1, Britain's space industry has come a long way. About 40 per cent of the world's commercial telecom satellites are made in the UK. And thanks to innovations such as CubeSat, and Astrium's bulging order book, Britain's presence in space is likely to grow.

"Whether watching sport on television, checking the news and weather, doing transactions with your bank or getting in-car navigation – none of it would be possible without satellite systems," says Dr David Williams, chief executive of the UK Space Agency. "And a lot of that technology is British." ■

Sean Blair is a journalist who works for the European Space Agency

FIND OUT MORE

http://bit.ly/earlysatellite
An ITN story from 1983 on the 'talking' British satellite, UoSAT-1

http://bit.ly/smartphonesatellite
Peer inside SSTL's smartphone satellite, STRaND-1

PROSPERO, ARE YOU RECEIVING?

Team tries to wake old British satellite from the dead

The now-defunct Prospero satellite and (below) the team attempting to re-establish contact

X-3, renamed Prospero after its October 1971 launch, holds a special place in the heart of UK space enthusiasts, because to this day it is the only British satellite successfully launched by a British rocket. Prospero was designed to detect micrometeorites and test solar cells, and functioned magnificently during its two-year working lifetime.

The satellite is still in low Earth orbit (where it is expected to remain for at least another century) and was last contacted 15 years ago. Operators at the Lasham ground station near Farnborough continued to check on it occasionally until the site was decommissioned in 1996. After that, communication was lost.

But on the 40th anniversary of Prospero's launch, a team at UCL's Mullard Space Science Laboratory tried to re-open lines of communication with the satellite.

"We wanted to see if Prospero remained operational," says Roger Duthie, a PhD student at the UCL lab in Surrey who led the efforts to get the craft talking again. The first snag was that the command codes needed to communicate with Prospero had been lost. It took studious detective work to pinpoint the necessary notes in the Kew National Archives.

The second problem? "Today's electromagnetic spectrum is chock-a-block," says Duthie. "There's overlap from various space and ground sources, making any Prospero signal hard to distinguish. We had to get a radio licence from Ofcom – it turns out Prospero's frequency is used locally by a 'business mobile', probably a taxi or courier firm. But since our two-metre VHF antenna broadcasts straight up, any interference should be minimal."

The team is equipped to transmit to Prospero, but not to detect any reply directly. Helpful radio hams listen out instead, one reporting a tantalising contact that might have been a return signal. Ofcom's initial licence has lapsed, however; Roger is awaiting a replacement.

"Once word got out, we received advice from Prospero team members," says Duthie. "The consensus is its onboard battery has probably failed but the solar panels might still be working."

The team plans to focus on orbits as the satellite is emerging into sunlight, ideally over the Atlantic, where there's less background noise than there is over Europe. If and when contact is re-established, examination of Prospero's telemetry would reveal how well it has weathered the last 40 years. You can follow developments at http://blogs.ucl.ac.uk/prospero-satellite.

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At last, an aquarium for busy people. biOrbs have built-in lighting and simple filtration that really works. The filter cartridges are easy to change and it only takes a few seconds.

The revealing truth about aquarium filters

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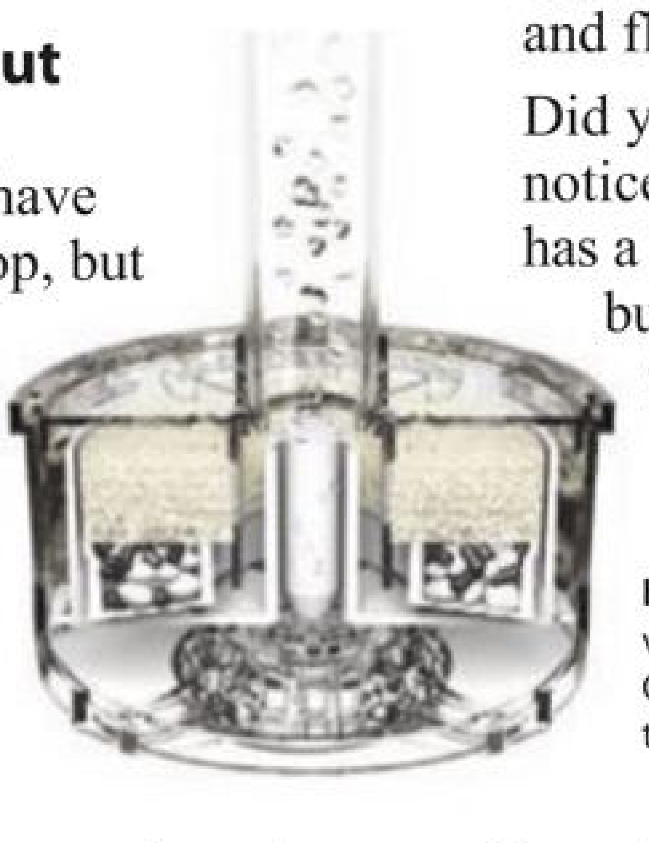

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> *"it's like watching fish in high definition"*

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x + y = the cute factor

We all know 'cute' when we see it. But what is it about young animals – and even inanimate objects – that makes them so adorable? **JV Chamary** finds out

With his large, round head and relatively small body, you couldn't get much cuter than Knut. On 23 March 2007, the cuddly, photogenic polar bear cub (whose name even rhymes with cute) became an international sensation after hundreds of journalists descended upon Berlin Zoo to see him.

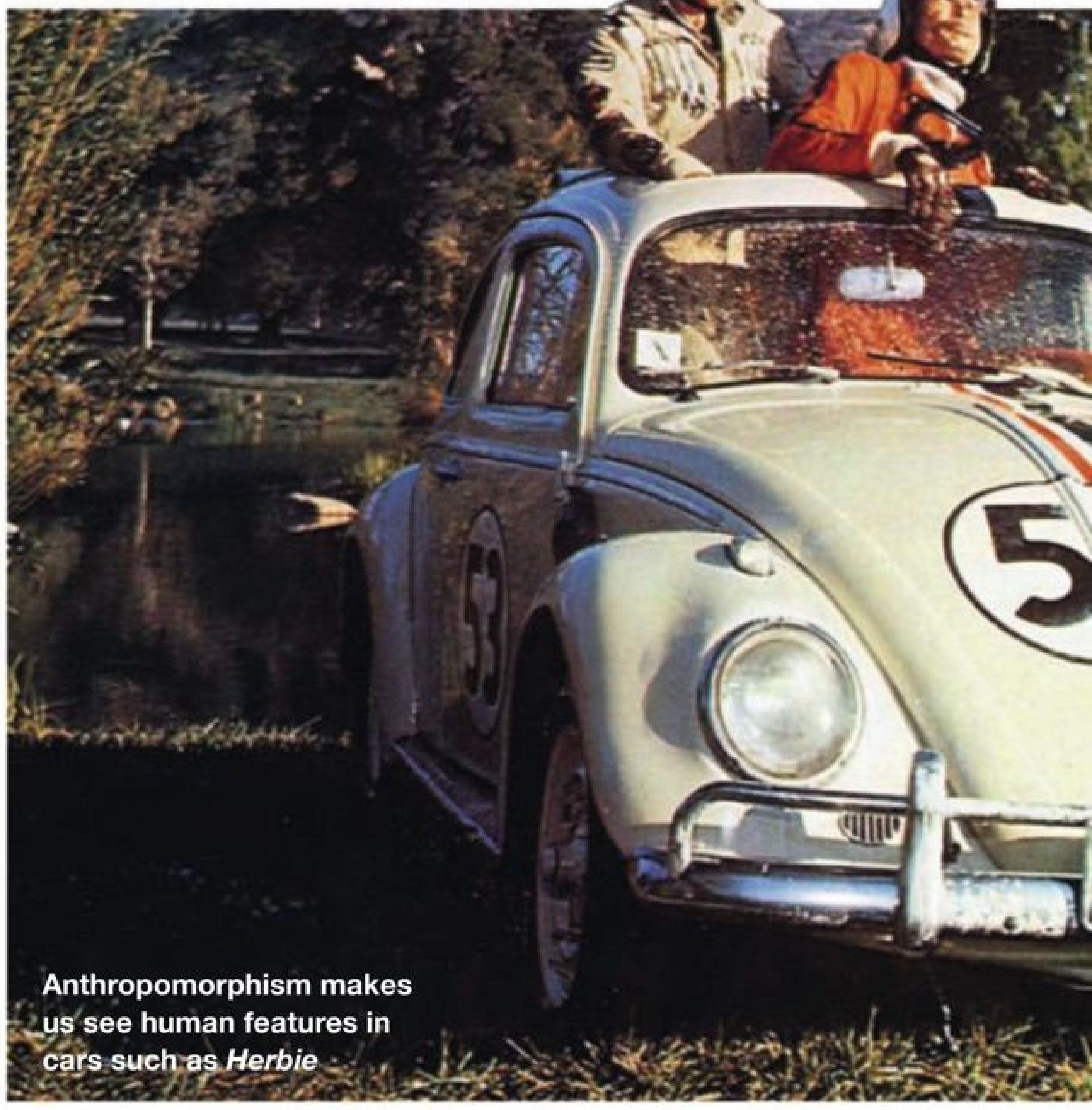
Knut mania helped attract an extra 300,000 visitors to the zoo in 2007, generating an extra €3 million from entrance fees alone. Knut also became the poster bear for habitat loss through global warming, appearing on the cover of *Vanity Fair*. Not bad for a cub rejected by his mother who wouldn't have survived in the wild.

By the time Knut died unexpectedly in March 2011, however, he was no longer the cute cub adored by all. The once puppy-sized bear had grown into a 2.5m-long beast – a worthy member of the world's largest species of land carnivore, who'd lost the cute features that had made him famous.

Scientists say the reason we find baby animals like Knut so adorable is that they remind us of babies from our own species. "The key characteristics of cuteness are essentially those of a babyish need for nurture," explains Dr Deirdre Barrett, an evolutionary psychologist at Harvard University. "A lot of the characteristics that draw us toward a human infant are fairly true of the young of other species – at least of other mammals."

In terms of physical features, cuteness means circular shapes, ▸

PRESS ASSOCIATION



Anthropomorphism makes us see human features in cars such as *Herbie*

▶ a big head relative to the body, a large cranium, small jaw, big eyes and bulging cheeks. Cute behaviour includes clumsy movements like crawling and waddling, plus expressions of neediness such as begging and crying. And according to 20th-century zoologist Konrad Lorenz, exposure to these child-like characteristics ('Kindchenschema') triggers innate parental instincts in adults, prompting feelings of affection and a desire to take care of a vulnerable infant.

But what stimulates this nurturing behaviour? We don't mistake puppies for people, and it's unlikely that adults look at young animals and think about the appeal of their large cranium – at least not consciously. To recognise that something looks like a baby, the brain probably combines individual features in a holistic way to create an overall impression – what psychologists call a 'gestalt'. But it's often individual features, rather than this gestalt, that create a stimulus.

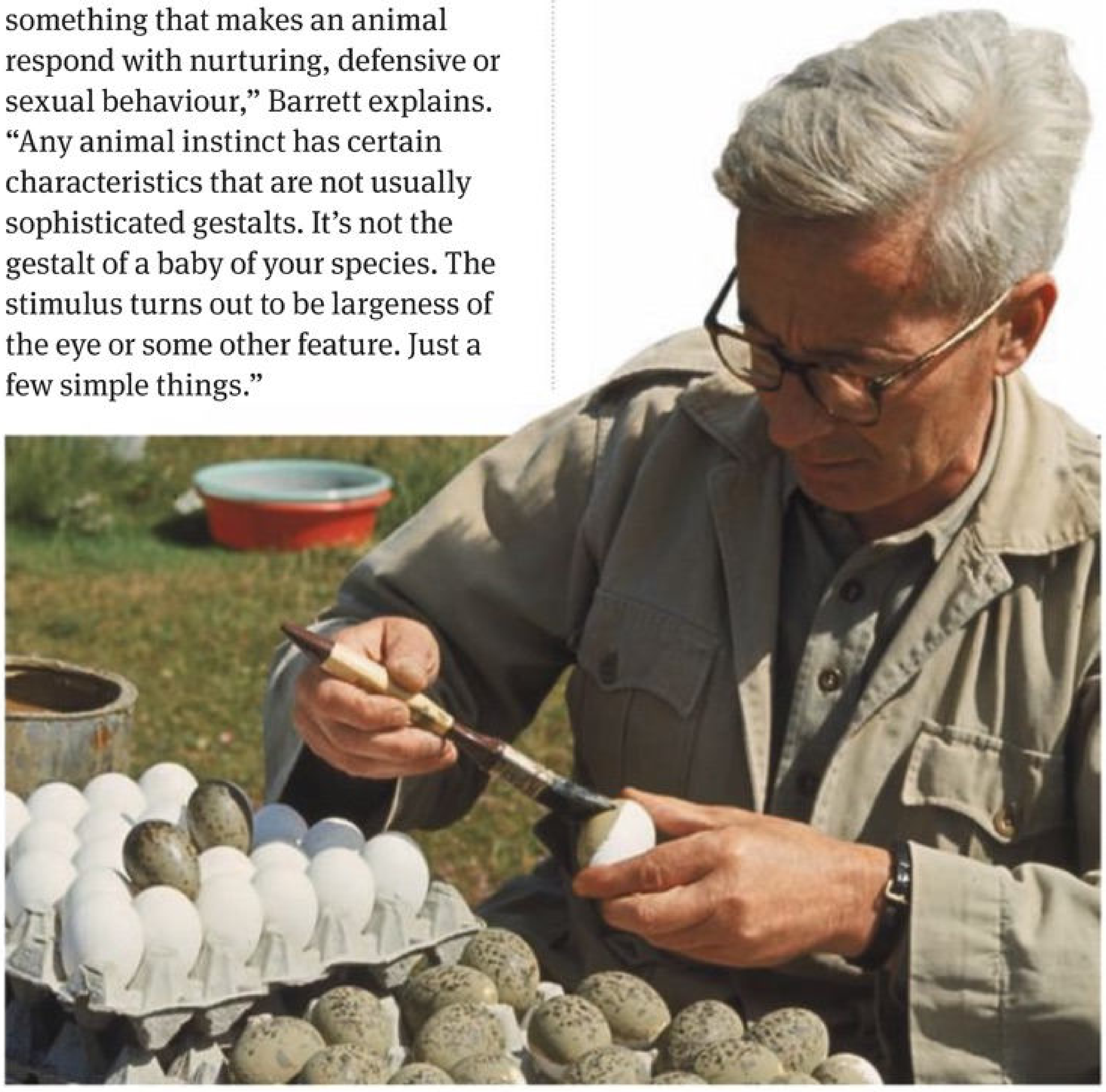
"A stimulus elicits an instinct, something that makes an animal respond with nurturing, defensive or sexual behaviour," Barrett explains. "Any animal instinct has certain characteristics that are not usually sophisticated gestalts. It's not the gestalt of a baby of your species. The stimulus turns out to be largeness of the eye or some other feature. Just a few simple things."

The individual components of cuteness can also stimulate nurturing instincts more strongly outside their natural context, an idea proposed by Lorenz's friend and fellow biologist Niko Tinbergen. The pair went on to win a Nobel Prize for their pioneering work on animal behaviour.

In one experiment, Tinbergen created artificial eggs out of plaster and showed that songbirds – which normally lay small, pale blue eggs speckled with grey – will prefer to sit on giant, bright blue ones with black polka dots. The fake eggs could be made several times larger than those found in nature, becoming so big that adult birds would repeatedly slide off and then get back on the egg. The research revealed that so-called 'supernormal stimuli' – including those that stimulate a nurturing instinct – can sometimes trigger a stronger response than normal stimuli.

This effect could explain why some people like animals and yet dislike human babies. Although most adults should prefer raising a child to a pet, kids also come with the baggage associated with having to look after them until they're old enough to leave home. "Something that elicits our visual cuteness [response] without stirring up those other human instincts can be purely cute," says Barrett.

"If people see a car front which looks like a face, they don't process it as an object"



Niko Tinbergen prepares to make some songbirds look foolish

Exploiting cuteness

Supernormal stimuli can also play a role in the marketing of consumer goods. Our brains are attuned to spotting facial features in the world around us, and this contributes to 'anthropomorphism' – a tendency to apply human qualities to other animals and even inanimate objects.

The headlights of a VW Beetle, for example, look like eyes. "If people see a car front which looks like a face, they don't process it as an object," says Dr Linda Miesler of the Zurich University of Applied Sciences in Switzerland, who studies the effects of product design on consumer psychology.

With consumers bombarded with similar tech specs – more megapixels, faster processors, higher fuel efficiency – it's increasingly hard for manufacturers to make their particular products stand out from the crowd. Enter the marketing experts, who've been giving objects human-like features to try and create an emotional connection between consumers and their products. "Anthropomorphism

SUPERSTOCK X2, PRESS ASSOCIATION, NATURAL HISTORY MUSEUM PICTURE LIBRARY, GETTY

creates a lot of positive responses in humans, which marketers want to exploit," says Miesler.

Miesler has tested peoples' emotional responses to cars by changing their 'facial features': the headlights (eyes), grille (nose) and air intake (mouth). She manipulated images to make these features 20 per cent bigger – a change that's large enough for people to perceive, but too subtle to notice consciously.

Participants were then shown random images of the original and cuter cars. As well as asking participants to rate cuteness, Miesler detected their emotional responses by attaching electrodes to their faces. This measured subtle activation of the 'smiling muscle' (cheeks) and 'frowning muscle' (forehead), and showed that people respond more positively to cars with cuter 'faces'.

Our fondness for cute features in the things around us was demonstrated in an essay by evolutionary biologist Stephen Jay Gould, who showed how Mickey Mouse evolved over 50 years from almost realistic rodent to cartoon caricature. And while the driving force behind cute characteristics is natural selection (see 'Survival of the cutest', right), man has also occasionally dabbled in artificial selection. The most prominent example is the domestication of dogs, which were ▸

SURVIVAL OF THE CUTEST

The evolution and development of cuteness in animals

HOW DO CUTE FEATURES DEVELOP?

The history of body features is explained by the evolution of their development. In a nutshell, millions of years of evolution has dictated what develops when. By default, animals should mature into an adult form that resembles their ancestor. Tweaking the genetic coding that controls this development can generate endless new forms.

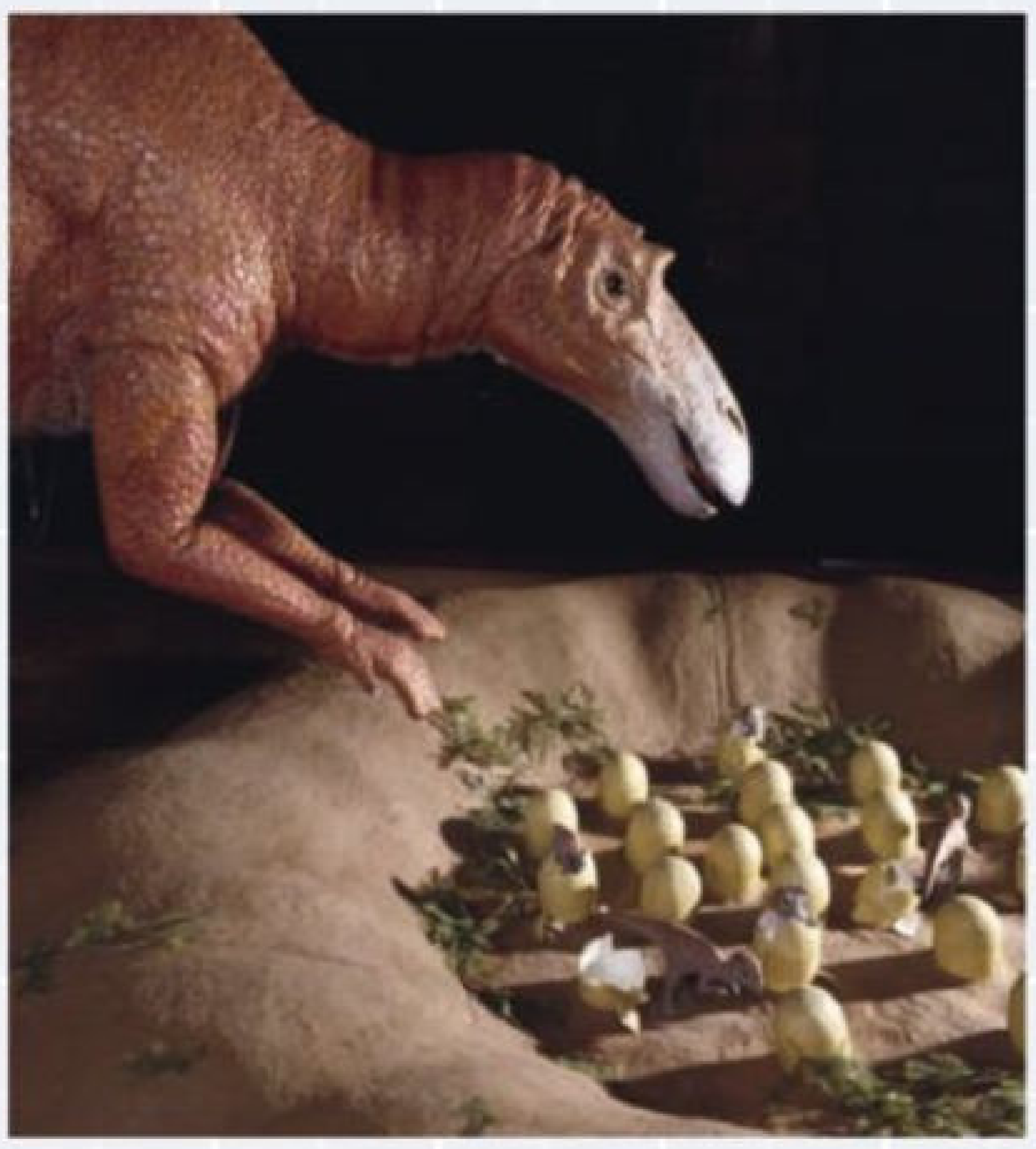
"Evolution is not only about genetic mutation producing new things, it's tinkering with what's already there," says Dr Ken McNamara, a palaeobiologist at Cambridge University. "You have the ability to shuffle characters to provide this great range of raw material, and that's what natural selection works on." Tinkering with the existing timing and rate of development can cause particular body parts to grow faster or slower, or for longer or shorter. Stop growth early, for example, and you end up with a newborn's big, cute, embryo-like head.

WHAT MAKES ANIMALS CUTE?

Natural selection has driven the evolution of cute features because they help animals survive in their surroundings. The features that they develop depend on resources: nutrients are limited by what mothers provide before birth, which leads to a trade-off in how animals invest in growing features during development. Baby mammals are fed milk, for example, so they don't need to spend resources on developing a large jaw for eating solid food.

Most animals lose their cute features as they mature. But this isn't always true, as in the case of adult koalas and giant pandas. Again, it's down to natural selection. The large, round head of pandas and koalas – a feature that adult mammals (or at least humans) find cute – is the result of natural selection favouring jaw structures that have allowed the animals to adapt to chewing tough vegetation.

WHEN DID CUTENESS FIRST EVOLVE?



If you define 'cuteness' as any characteristic that triggers a nurturing instinct, then it's at least as old as the dinosaurs. Though most dinosaurs had to develop adult features to fend for themselves early in life, some nurtured their offspring – like their descendants the birds. Fossils have been uncovered of 75 million-year-old *Maiasaura* ('caring mother lizard') nests containing eggs, while *Massospondylus* nests date back 190 million years. But 'cute characteristics' such as a large cranium are far more ancient. Biologists call these features 'paedomorphic traits', or child-like shapes. According to McNamara, even the juvenile stages of trilobites (a 500 million-year-old group of extinct marine arthropods) had paedomorphic traits. Whether cute characteristics stimulated nurturing instincts in other ancient animals is unknown.

The sound of crying babies can speed up reaction times

▶ probably bred from wolves that displayed sociable, almost tame and child-like, behaviour.

Barrett believes that supernormal stimuli are responsible for some of the problems in modern society, such as hijacking our need for salt and sugar to drive a desire for exaggerated amounts of these nutrients in junk food. But she says cute supernormal stimuli are fairly harmless. "We may spend some money on stuffed toys and cute objects, some time and resources, but the hijacking of nurturing instincts, which is essentially what the perception of cuteness is, is much milder."

The ugly side of cute

Research on cuteness has important applications in welfare, as it can shed light on what happens to the nurturing instinct when babies are less cute than normal. One example is cleft lip, a condition that is relatively common in the UK (occurring in one in 700 newborns) where the face fails to develop properly, leaving a gap above the mouth.

Although the deformity involves only a minor change in facial features, it has significant adverse effects, being associated with behavioural, emotional and cognitive problems in childhood, and low self-esteem later in life. These problems start at birth, as parents seem less able to create an emotional attachment to their baby.

In a recent study by neuroscientists at Oxford University and Aarhus University in Denmark, adults were shown images of infants with and without a cleft lip, and told they could view photos for longer or shorter periods by pressing buttons. They found that people would view babies with a cleft lip for less time, suggesting that relatively minor differences in physical cuteness could have a major impact on parenting.

"It's almost as if your brain has designed you to care for babies"

Our brains are hardwired to want to nurture infants

ALAMY, GETTY

"Even a small change to the infant schema configuration [a baby's features] can mean a radical difference in the care you give them," says Professor Morten Kringelbach, who led the research. "From a clinical point of view, we could potentially help parents learn to ignore that feature, to use their cognitive abilities to react normally to a baby, even if it has a cleft lip."

Another of Kringelbach's experiments, in which people viewed pictures while in a brain scanner, revealed that a specific region of the brain lights up after seeing babies, but not adults. This region, the orbitofrontal cortex, is activated incredibly quickly, within 0.13 seconds – even before the parts of the brain responsible for recognising faces. "It happens so early that it's almost certainly unconscious, so it's almost as if your brain has designed you to care for babies," says Kringelbach.

So it seems our love of cuteness is hard-wired in the brain. And because the orbitofrontal cortex develops during the first 20 years of life, that neural circuitry is probably reinforced through learning. This means it might be possible to reconnect circuits that aren't responding correctly to a baby's physical features, which can happen in parents with post-natal depression.

Visual features aren't the only cute stimuli that trigger a nurturing response. Kringelbach's team has also discovered that adults perform better at Whac-A-Mole (an arcade game requiring fast reaction times) after listening to recordings of a crying baby. Kringelbach suggests that baby cries could even be used as a 'legal doping' tactic to boost performance at the Olympics. "Imagine, before the 100 metres, you listened to baby cries and you became much faster."

Whether it's adorable faces or annoying sounds, the stimuli that trigger nurturing instincts involve more than just aesthetic appeal. Cute characteristics could be considered a sneaky strategy that's evolved to help young animals survive by encouraging adults to take care of them.

"In many ways, 'cute' can be thought of like a Trojan Horse," says Kringelbach. "It's something that, for whatever reason, we can't help ourselves but like." ■

Dr JV Chamary is a biologist and features editor of **Focus**

FIND OUT MORE

http://bbc.in/cutecollection
BBC videos of baby animals

Supernormal Stimuli: How Primal Urges Overran Their Evolutionary Purpose
by Deirdre Barrett (Norton, 2010)

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WORKING OUT WILLPOWER

Like muscles, the brain can be exercised to strengthen self-discipline. But as **John Tierney** explains, new research shows that strong willpower comes from surprising sources

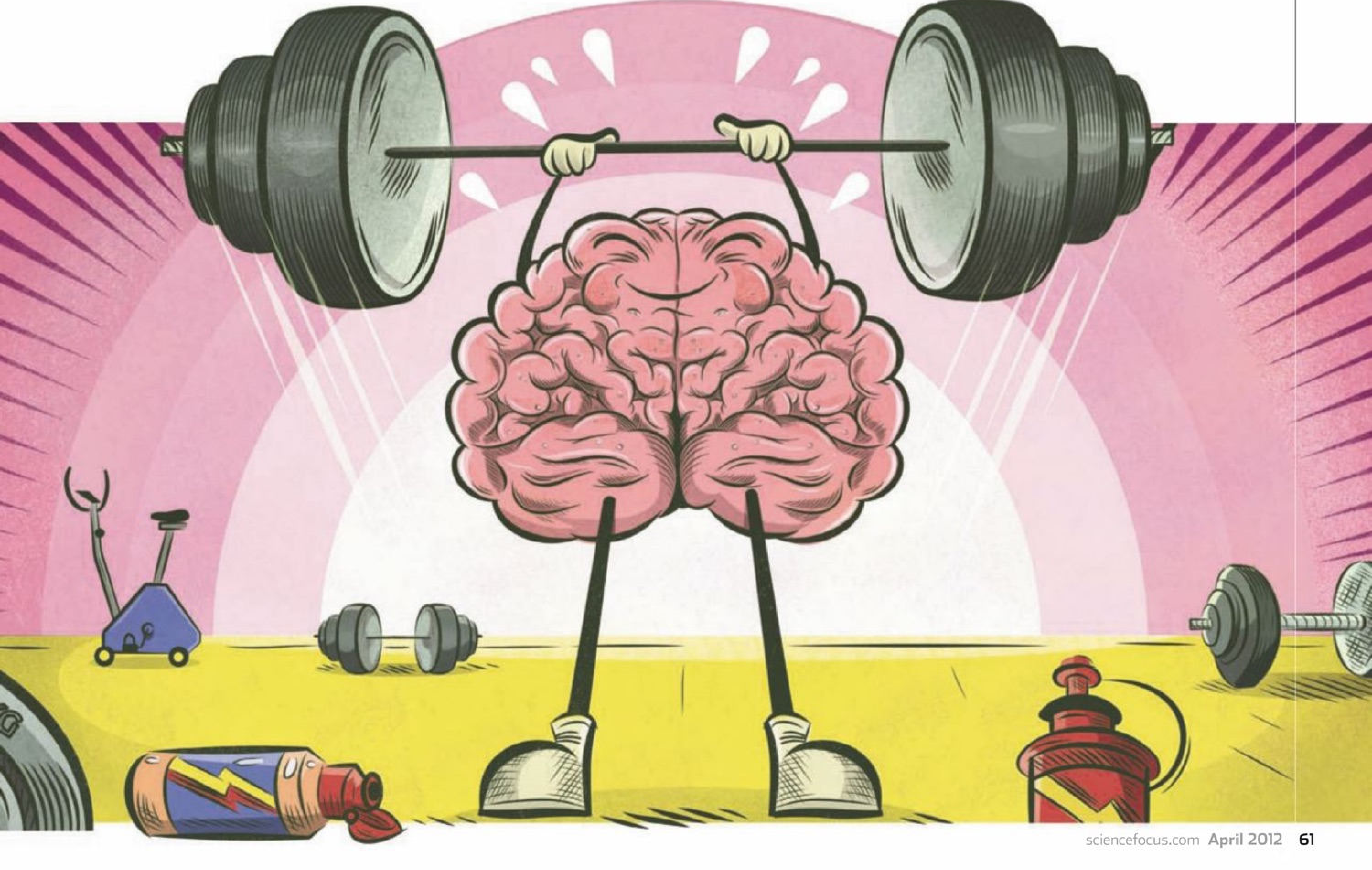
Willpower is no longer just a metaphor. For much of the 20th century, psychologists saw the 'power of will' as a quaint folk notion, a bit of pseudoscience popularised by Victorians obsessed with weak character who, to withstand the novel temptations invented by the Industrial Revolution, imagined relying on some inner equivalent of the steam engine.

In *Self-Help*, one of the best-selling books of the 19th century, reformer Samuel Smiles described willpower as an energy that "enables a man to force his way through irksome drudgery and dry details, and carries him onward and upward."

"It accomplishes more than genius," he wrote. "Energy of will may be defined to be the very central power of character in a man – it is the Man himself. It gives impulse to his every action, and soul to every effort."

But the Victorians had no idea – much less any scientific evidence – of what this energy might be. Freud theorised that the self depended on mental activities involving the transfer of energy, but his energy theory of the self was generally ignored by subsequent researchers. It wasn't until relatively recently, ▸

ILLUSTRATION BY ROBIN BOYDEN



Cookie monster: Professor Roy Baumeister

▶ after psychologists noticed that children able to resist temptations in lab experiments went on to do much better in life (see 'Self-control = success', p63) that social scientists began looking for ways to test the Victorian idea of character. If there was an inner source of energy, how could it be observed?

The answer was to start with warm cookies, baked in the laboratory of Professor Roy Baumeister. When students (the experimental subjects) walked into the lab, they were already hungry because they'd been fasting, and now they were in a room suffused with the aroma of fresh-baked chocolate chip cookies. The students sat down at a table with three culinary choices: the cookies, some pieces of chocolate, and a bowl of radishes. Some were invited to eat the sweet treats, the unlucky ones were assigned just raw radishes.

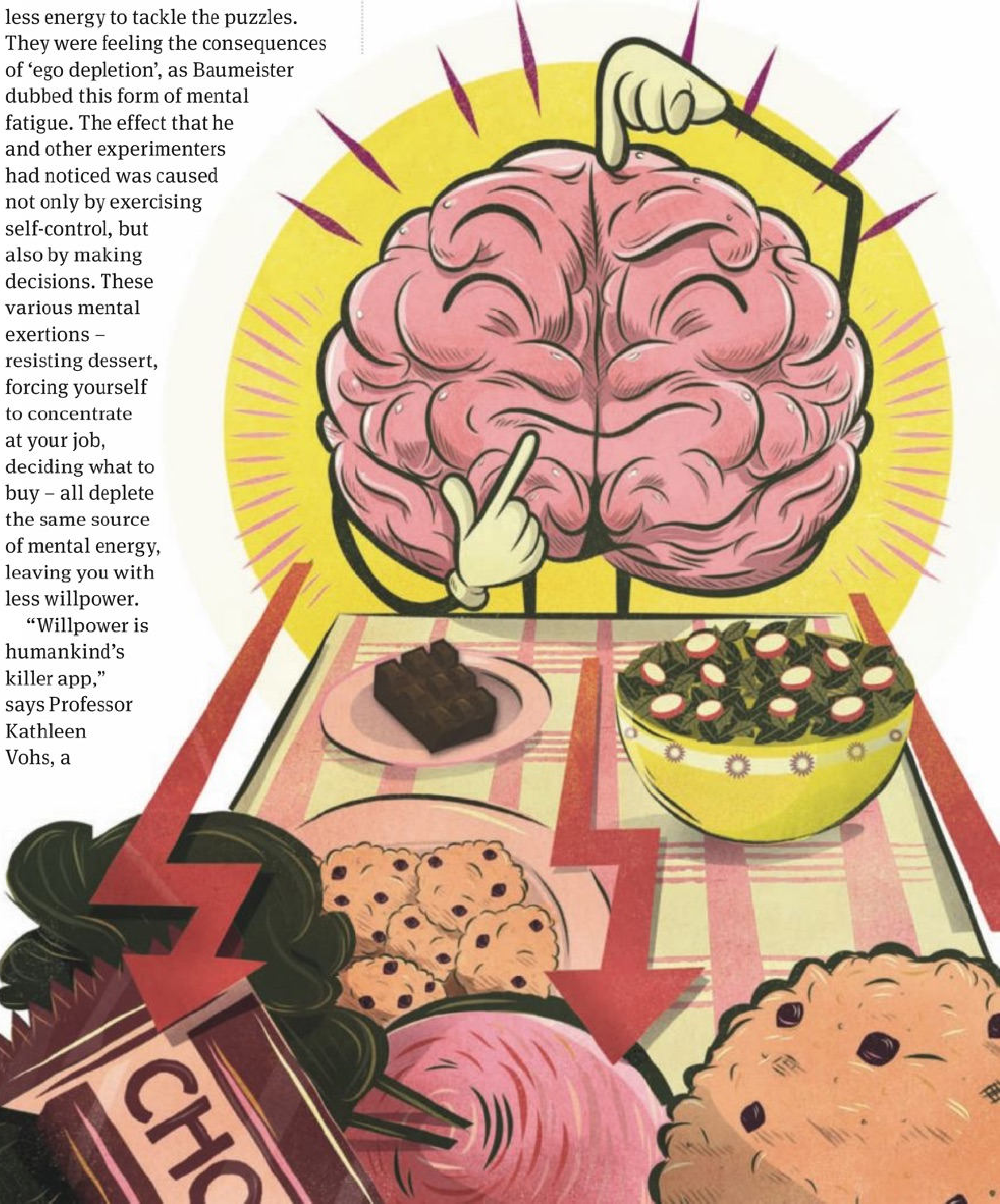
Baumeister's researchers left the students alone with the food, and observed them through a hidden window. The ones in 'the radish condition' clearly struggled with the temptation. Many gazed longingly at the cookies before reluctantly biting into a radish, while some picked up a cookie to savour the pleasure of its freshly baked smell. But nobody actually tasted the forbidden food.

Then the students were taken to another room and given geometry puzzles. The students thought they were being tested for cleverness, though the puzzles were actually unsolvable. Those who'd been allowed to eat biscuits and sweets typically worked on the puzzles for about 20 minutes, as did a control group who were also hungry but weren't offered any food.

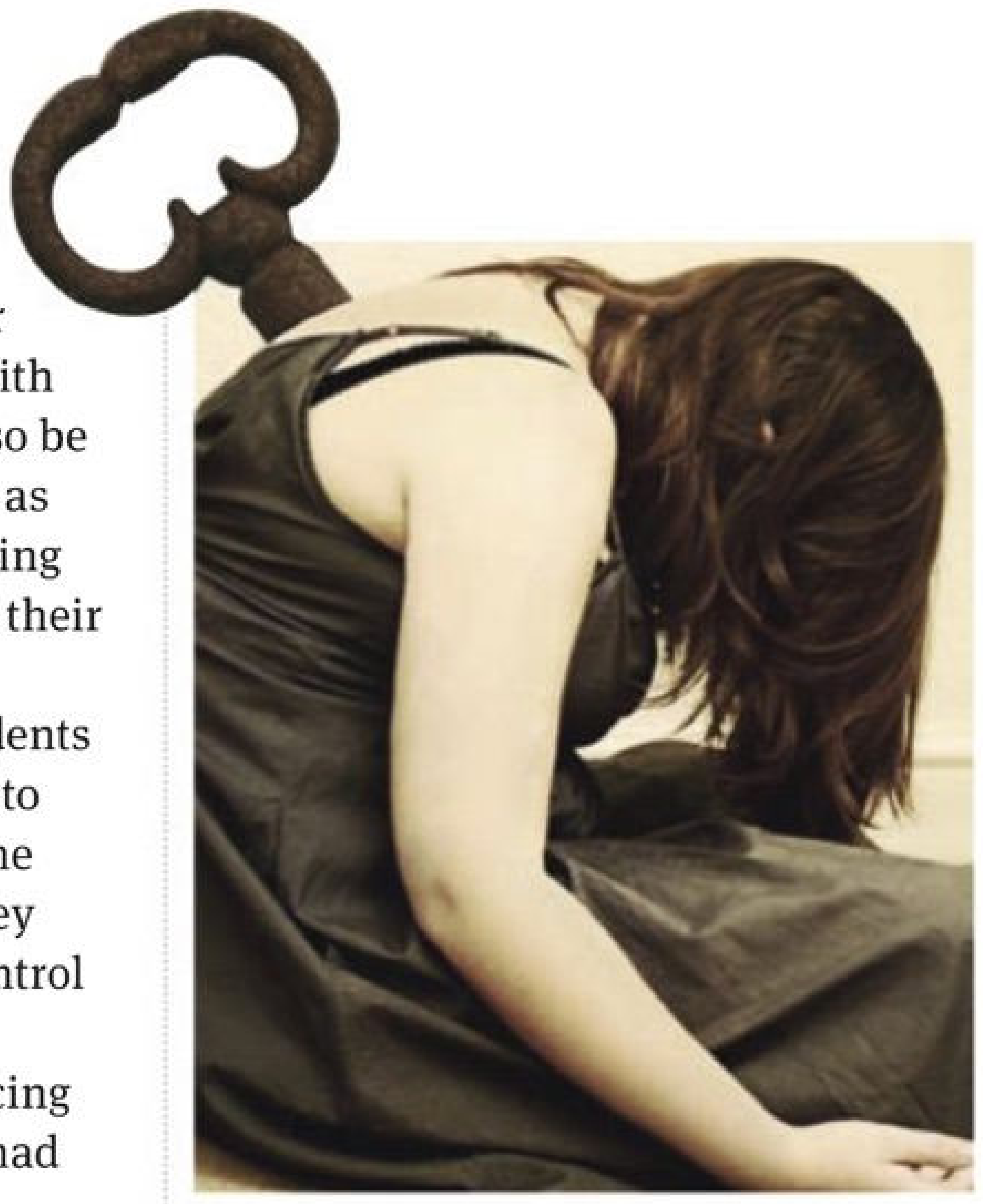
The sorely tempted radish eaters, though, gave up in just eight minutes – a huge difference by the standards of lab experiments. Although they'd resisted the temptation of the sweet foods, the effort had left them with less energy to tackle the puzzles. They were feeling the consequences of 'ego depletion', as Baumeister dubbed this form of mental fatigue. The effect that he and other experimenters had noticed was caused not only by exercising self-control, but also by making decisions. These various mental exertions – resisting dessert, forcing yourself to concentrate at your job, deciding what to buy – all deplete the same source of mental energy, leaving you with less willpower.

Willpower is humankind's killer app. It enables people to look beyond the immediate

"Willpower is humankind's killer app," says Professor Kathleen Vohs, a psychologist at the University of Minnesota. "It enables people to look beyond the immediate to what's good for them longer-term. With its power, though, comes fragility: people just can't be equally strong at self-control all the time. Like a cheetah and its super-fast running speed, humans as a species excel at self-control – but only for a limited time, and then we need respite."



BILL LAX/FLORIDA STATE UNIVERSITY, GETTY, CORBIS, ILLUSTRATION BY ROBIN BOYDEN



Willpower requires a good supply of energy

The mind muscle

Researchers compare willpower to a muscle that gets fatigued with use. But like a muscle, it can also be strengthened through exercise, as Baumeister found after instructing some of his students to work on their posture for a few weeks.

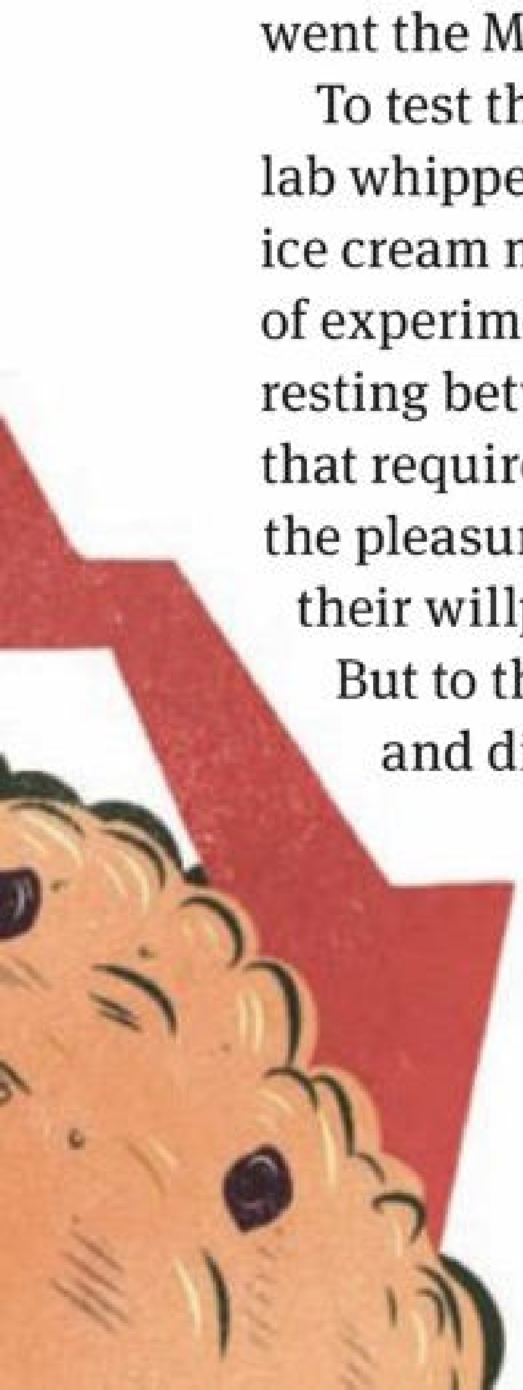
Instead of slouching, the students were told to remind themselves to sit or stand up straight. When the students returned to the lab, they demonstrated improved self-control in tasks that had nothing to do with posture. By repeatedly forcing themselves not to slouch, they had strengthened their willpower.

"You really can 'build character', as the Victorians used to say," Professor Baumeister explains. "Some very simple exercises in self-control, like sitting up straight or trying to always speak in complete sentences, will build up your willpower for all kinds of other, more important, activities."

Once willpower was revealed to be a physical phenomenon, researchers began looking for the source of the energy. They found it by accident after a failed experiment inspired by Mardi Gras. Traditionally, Mardi Gras (literally, 'Fat Tuesday') is a final fling of self-indulgence before the Lent period of fasting and other forms of self-sacrifice begins. By relaxing before Lent, perhaps people could store up the willpower necessary to sustain themselves through the coming weeks of self-denial – or so went the Mardi Gras theory.

To test the theory, Baumeister's lab whipped up deliciously thick ice cream milkshakes for a group of experimental subjects who were resting between two laboratory tasks that required willpower. Sure enough, the pleasurable indulgence improved their willpower for the next task.

But to the scientists' surprise – and disappointment – the same effect was observed in a control group that drank a distinctly undelicious low-fat dairy gloop. They reported no pleasure from drinking it, yet their willpower improved anyway.



So if it wasn't the pleasure, could it be the calories? The notion seemed strange – for decades, psychologists had been studying performance on mental tasks without worrying about it being affected by drinking a glass of milk. They liked to envision the human mind as a computer, focusing on the way it processed information, but had ignored one essential part of the machine: the power supply.

Sugar solution

Now the scientists began studying the power supplied by glucose, the simple sugar manufactured in the body from all kinds of foods, not just sweet ones. Researchers measured glucose levels in the bloodstream of subjects before and after performing simple tasks, like watching a video in which words flashed at the bottom of the screen. Some people were told to ignore the words; others were free to relax and watch however they wanted.

Afterwards, there was a big difference: glucose levels remained constant in the relaxed viewers, but dropped significantly in the people who'd been trying to avoid the words. That seemingly small exercise of self-control was associated with a big drop in the brain's fuel of glucose.

To establish cause and effect, the experimenters tried refuelling the ▶

SELF-CONTROL = SUCCESS

How important a virtue is self-control? The evidence has been accumulating for decades, starting with an experiment at Stanford University in California, in which four-year-olds were left alone with a marshmallow.

The children were told they could eat it whenever they wanted, but if they held off until the experimenter returned, they would get a second marshmallow. This simple test turned out to be a remarkably good predictor of future success. The kids who managed to hang on for the second marshmallow went on to do better in school, be more popular and earn more money as adults.

Last year, the strongest evidence yet on early self-control was published. An international team of researchers tracked 1,000 children in New Zealand from birth until the age of 32. The kids with high self-control grew into adults who had better physical health, with lower rates of obesity, fewer sexually transmitted diseases, and even healthier teeth – good self-control apparently includes regular brushing.

On the flip side, those children who exhibited poor self-control tended to wind up poorer financially later in life. They worked in lower-paying jobs, had little money in the bank and were less likely to own a home or have money set aside for retirement. They grew up to have more kids raised in single-parent households, presumably because they had a harder time adapting to the discipline required for a long-term relationship. The children with good self-control were much more likely to wind up in a stable marriage and raise children in a two-parent home. Finally, the children with poor self-control were more likely to end up in prison.

Those who exhibit higher levels of self-control as children often go on to lead more successful lives as adults

Not surprisingly, some of these differences could be correlated with intelligence, social class and race – but all these results remained significant even when those factors were taken into account.

In a follow-up study, the same researchers looked at brothers and sisters from the same families, so that they could compare children who grew up in similar homes. Again, over and over, the sibling with the lower self-control during childhood ended up worse off during adulthood: sicker, poorer, more likely to spend time in prison.

The results couldn't be clearer: self-control is a vital strength, and key to success in life.

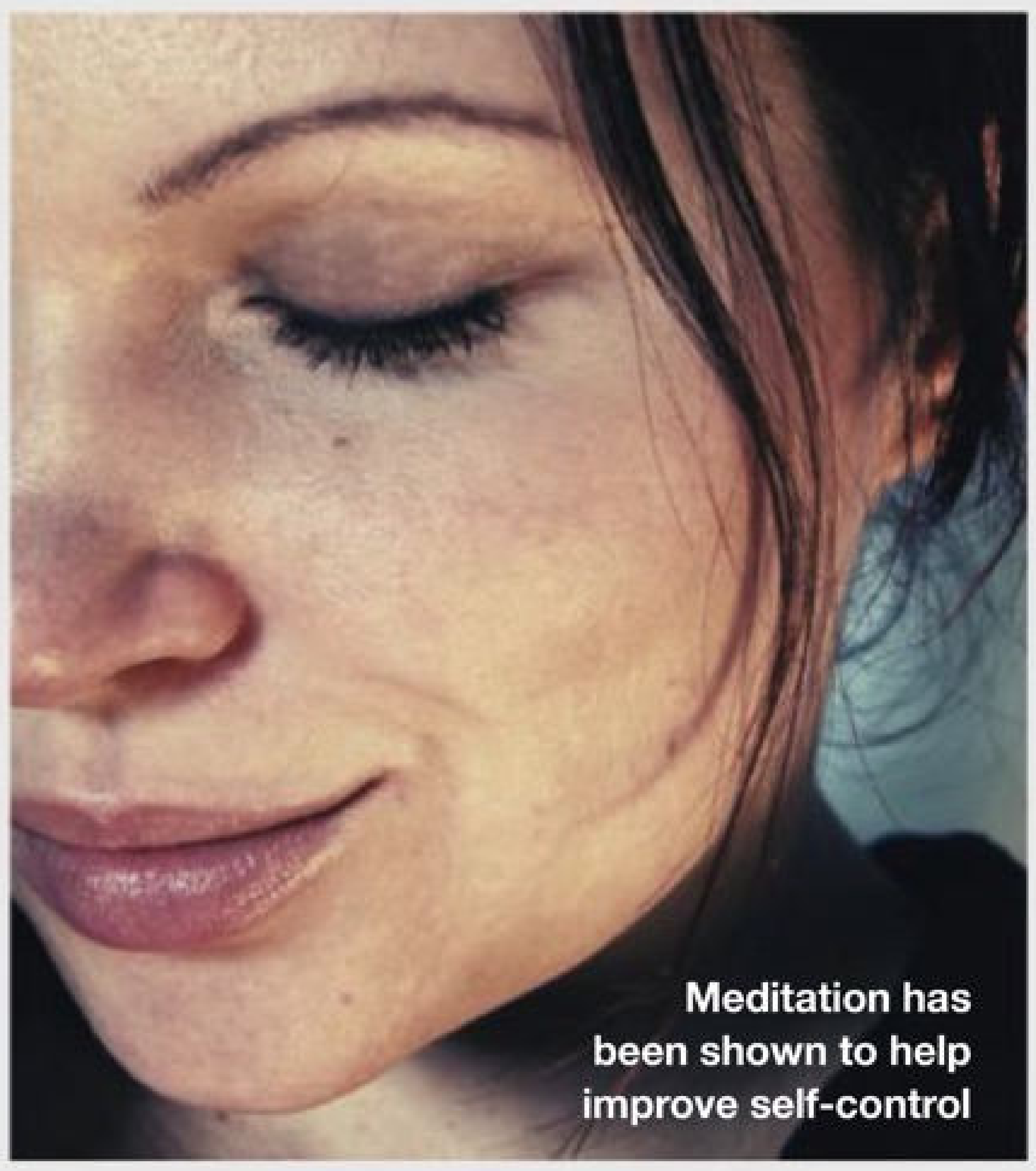
PUMP UP YOUR WILLPOWER

Tips and tricks to enhance your self-discipline

STRENGTHEN YOUR MIND MUSCLE

There are now almost a dozen major studies showing that willpower can be increased over time by doing simple exercises in self-control, such as sitting up straight instead of slouching, or brushing your teeth with the 'wrong' hand. The key is to change a habitual behaviour. You might, for instance, try to speak without using contractions, or without saying "um."

Meditating or saying prayers might also help. When neuroscientists observe people meditating or praying, they see strong activity in two parts of the brain that are also important for self-regulation. This is probably one reason why religious people tend to score quite highly in measures of self-control: they've already built up their willpower through the self-discipline rituals involved in many religions, such as saying daily prayers or fasting at certain times of the year.



Meditation has been shown to help improve self-control

Gadgets can help you stick to an exercise or weight-loss plan

MONITOR YOUR PROGRESS

People who weigh themselves every day tend to lose more weight than those who do it weekly. And those who keep a food diary lose more weight than those who don't keep track. Whatever your goal, monitoring progress will improve your odds. It can be a bore, but it's becoming easier than ever, thanks to digital tools that will do the dreary tracking for you.

These gadgets and apps will track your weight, how many calories you eat, how many steps you take each day, how long you sleep, how your moods change, where you spend your money or how much time you waste surfing the web. They can alert you when you've exceeded your budget for food or money; they'll even send messages to your friends or boss (if you want them to). You can find an assortment of them at websites like quantifiedself.com and lifehacker.com.

CONSERVE YOUR WILLPOWER

In a recent German study, researchers were surprised to note that people with stronger self-control spent less time resisting desire than other people did. The finding seemed paradoxical, until an explanation emerged: these people have less need to use willpower because they're beset by fewer temptations and inner conflicts. They arrange their lives to avoid problem situations; they stay away from all-you-can-eat buffets.

No matter how strong your willpower, it will become depleted if you rely on it in crisis after crisis. You can conserve willpower by minimising temptations and establishing habits that don't require conscious exertion. You can further conserve willpower by outsourcing self-control – by, say, working out with a friend rather than solo. You're letting peer pressure do some of the work for you, and conserving your own willpower for the day's unexpected challenges.

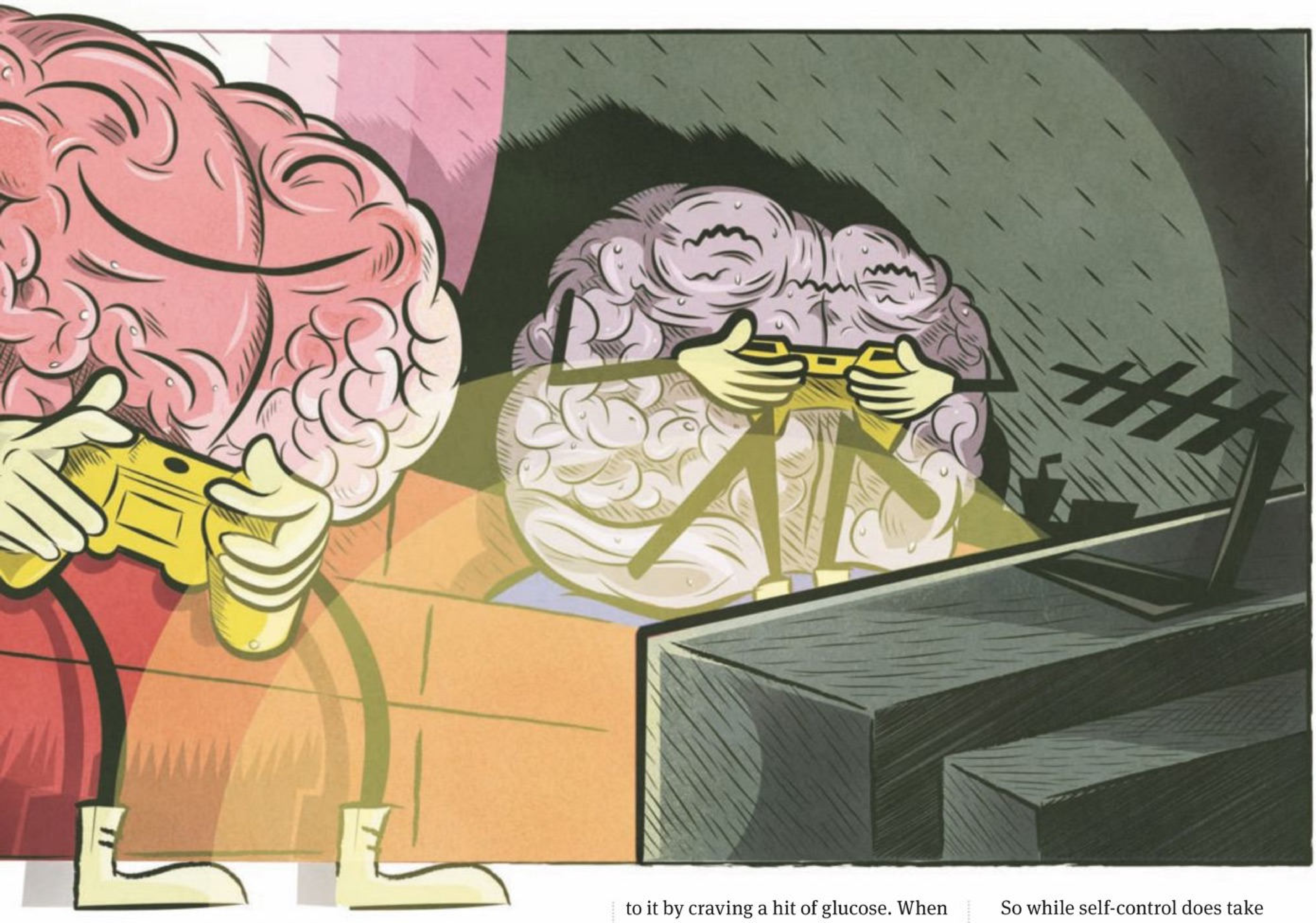
Rely on a friend, not your willpower, to keep you going on a run

GETTY X2, NIKE, ILLUSTRATION BY ROBIN BOYDEN

▶ brain in a series of experiments involving lemonade mixed with either sugar or a diet sweetener. The sugar gave subjects a short-lived burst of glucose, whereas the diet sweetener didn't furnish any. The effects showed up clearly when subjects were asked to play a computer game that seemed easy enough, but soon became impossibly difficult. Everyone got frustrated as the game went on, but those who got a sugar-filled lemonade grumbled quietly and kept playing. The others started swearing and banging the computer, and gave up.

"The benefits that accompany self-control have metabolic costs," explains Dr Nathan DeWall of the University of Kentucky, one of the team who identified the sugar-willpower link. "All psychological activities require glucose, but self-control requires a large amount."

The pattern showed up time and again as experimenters tested people in more situations. Deprived of glucose, people had less self-control and made worse decisions, becoming more prone to irrational



biases and settling for quick payoffs instead of following better, long-term strategies. But a dose of glucose would mitigate the 'ego depletion' effect and sometimes reverse it completely.

Deprived of glucose, people had less self-control and made worse decisions

Dog tired

Ego depletion has even been observed in dogs. In experiments by DeWall and Holly Miller, after dogs obeyed sit and stay commands for 10 minutes they performed worse on self-control tests and made risky decisions.

"They became more likely to approach a potentially dangerous dog that was barking wildly at them," says Dr Miller. "Dogs share more than the sofa with their owners – they show the same sensitivity to the depleting effects of self-control exertion."

And just like their owners, dogs respond to refuelling. A dose of glucose restored the dogs' self-control and made them less likely to risk a dangerous confrontation.

We may not be consciously aware of ego depletion, but our bodies react to it by craving a hit of glucose. When people have more demands for self-control in their lives, their hunger for sweets increases, though their hunger for food in general does not. In the lab, students who have just performed a self-control task eat more sugary snacks, but no more savoury snacks. What's more, even simply *expecting* to have to exert self-control seems to have the same effect.

It's ironic that researchers in self-control are so fond of giving their experimental subjects sweets, given that many people wish for the willpower to resist them. And all these results don't provide an excuse for guzzling chocolate outside the lab, either. Scientists offer sweet foods for short-term convenience: a sugar-filled drink only provides a quick rise in energy, promptly followed by a sugar crash that leaves you feeling more depleted. Better to rely on foods with a low glycaemic index, meaning they're converted to glucose more slowly. The result is a steadier supply of fuel for the sort of virtue that Samuel Smiles preached in the Victorian era.

So while self-control does take will, we should also appreciate the sources and limits of that power. "The research has made me realise how precious and marvellous our willpower is," says Roy Baumeister. "I've become sensitive to when my ability is depleted. When things start to overwhelm or bother me, I'm better able than before to realise that it's not really the things themselves, but rather that my own resources are depleted, and I need to rest and get some food and wait for the nutrients to get to the bloodstream."

Until the nutrients come to the rescue, Baumeister concentrates on following a simple rule: no glucose, no willpower, no big decisions. ■

***John Tierney is co-author (with Prof Roy Baumeister) of* Willpower: Rediscovering Our Greatest Strength**

FIND OUT MORE

http://bbc.in/R4marshmallow
Radio 4 programme on the marshmallow experiment

Star man

Neil deGrasse Tyson, Director of New York's Hayden Planetarium and author of *Space Chronicles*, tells **Daniel Bennett** why America should be back in space

Focus: **In your new book you argue that the USA needs to get astronauts back into space. Why?**

Neil deGrasse Tyson: I'm not here to tell America what to do. What I am saying is that without big, bold space ambitions, we stop investing in our future. And investing in our future guarantees a healthy economic state.

I'm not just talking about the great spin-offs that come from space technology. I'm talking about a complete shift in attitude where instead of just living day to day, people think about how they'll live tomorrow. It would be a tomorrow where anything is possible because your country is involved in a major venture that defies belief. When Neil Armstrong went to the Moon, we didn't say, "Those guys went to the Moon." It was, "*We* went to the Moon."

F: **Would just getting back onto the International Space Station be enough? Or should NASA be more ambitious than that?**

NT: If you're doing the same thing over and over, you're not advancing a frontier. So much of the malaise regarding space exploration is understandable, because we were boldly going where hundreds had gone before, back into low Earth orbit. Yes, we advanced an engineering frontier, building a space station that's got the area of a football field. I'm not detracting from the efforts of the past couple of decades. But when you want to advance a new space frontier, you need a new goal. Perhaps we should be looking to put an astronaut on Mars.

F: **Why not just continue to send robotic rovers instead?**

NT: If all we were after from space exploration was scientific discovery, then we *could* just send robots. They can do a much better job than people. In fact, you still need to send the robots with the humans to do all the work. But that's not the only goal here – people conflate the two forces. Scientific discovery has piggybacked the major adventures of nations forever. But on average over the last 50 years, NASA's science budget has never been over a quarter of its total budget. NASA has never primarily been about science.

F: **So what do we get out of sending astronauts rather than robots?**

NT: I'm saying that sending people grabs headlines. Robots were on the Moon in the 1960s but we didn't hear about it, because the world was completely distracted by humans that were going there. You wanted to know who these people were, what their

DAVID GAMBLE, ILLUSTRATION BY DANNY ALLISON

> *"Much of the malaise regarding space exploration is understandable, because we were boldly going where hundreds had gone before, back into low Earth orbit"*

background was and what kind of stuff they were made of.

History has shown there's a vicarious thrill we all take in one of our own advancing a frontier. That's who you build statues of, who schools are named after, who stories are written about. If you're not engaged in that kind of activity, none of that happens, and people aren't inspired to get involved pushing science, technology and engineering forward.

F: Being cynical, can we actually measure these benefits?

NT: It's a perfectly legitimate question. The rewards are subtle. If we went to Mars, the whole nation would readjust how it thought about tomorrow. This sea-change shifts how we value what it is to study science, technology, engineering and math. This in turn influences the students that come out of the other end of the pipeline, and what they end up doing with their lives. When you stoke that kind of ambition, while growing the number of engineers and scientists, you create entire new economies.

F: What about CERN… have you been keeping a professional eye on their recent findings, and what do you make of it all?

NT: First of all, I'm jealous! We [America] could have made all those discoveries 30 years ago, but Congress cut the funding for the Superconducting Super Collider, which was a huge accelerator that was scheduled to be built in Texas. It was designed to explore three times the energy range of CERN, but its funding was cut and it was scrapped in '93. To take an idea like the Collider, and turn it into a reality, is an example of exactly the kind of enterprise I'm talking about.

Now, to take off my American hat and put on my scientist's hat… it's great somebody's doing it. The good thing about physics is that if you design an experiment that explores some sort of parameters that haven't been looked at before, you're almost guaranteed to find something. So in this case it's the levels of energy that it's reaching. CERN was designed to explore higher energies than anything before it. When you do that, you're poking nature in ways that no-one ever probed before.

F: And finding faster-than-light neutrinos – or not? Where do you stand on that?

NT: One of the problems of the experiment is that it's relying on timekeeping devices that were not part of the design of the experiment. Instead, it's using GPS satellites that were presumed to have all the accuracy that was needed.

I'm betting that there's still some error in the chain of measurements from the GPS satellites. It may be that it took this experiment to show that there's a flaw in the GPS timers.

F: Why did you decide to become an astrophysicist?

NT: It actually all started with a visit to my local planetarium. I looked up, the lights dimmed, the stars came out, the voice of the planetarium director came from the sky… and that was it, my mind was blown.

And then 27 years later I came back, as the Director. It wasn't an ambition of mine – it just turned out that way. It might have been bigger news in a smaller city but New York is too big for it to make anybody's headline.

F: What kind of science still blows your mind?

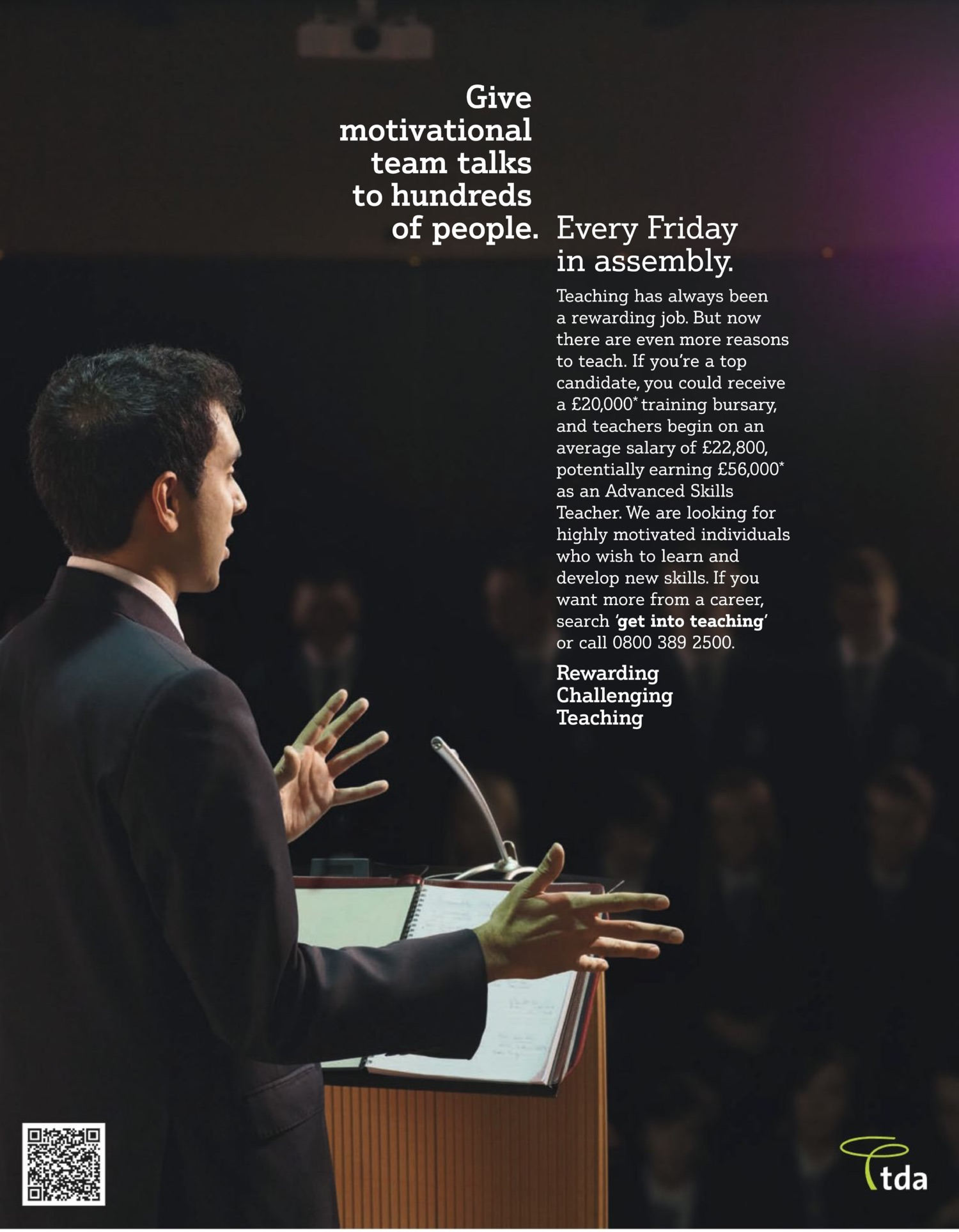
NT: Well, images always do it for me, particularly those from the Hubble telescope. That's one of the only scientific instruments in the world where its images don't even require captions – you just sit there and take in their majesty. I've found that in other areas, when it comes to things like odd biological creatures and so on, images do always require a caption – you need an expert to highlight why it's interesting.

I think scientists in general could benefit from thinking about how their work can be presented in a way that makes it a fascinating subject – even to those that aren't closely involved in their field. ■

FIND OUT MORE

To follow Neil deGrasse Tyson on Twitter, visit **www.twitter.com/neiltyson**

Space Chronicles: Facing The Ultimate Frontier goes on sale in April and is published by WW Norton



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FUTURE OF GAMING

Over the next six pages we will be looking at what the biggest publishers have to offer gamers in the coming months...

NCSOFT

NCSOFT STRIVES TO SET A BENCHMARK FOR FUTURE MMO GAMES WITH THE NEXT ITERATION OF ITS AWARD-WINNING SERIES

The immense popularity of the first *Guild Wars* title could easily have led its publisher NCsoft and developer ArenaNet to create an updated clone of its MMO in the sound knowledge that it could still pack its servers to the rafters.

Guild Wars 2

But with *Guild Wars 2*, the award-winning Washington-based studio wanted to challenge the conventions of the modern day MMO with a fresh approach that gives players a more rounded adventure experience, one that isn't suffocated by traditional grind-based gameplay.

The evolution of the *Guild Wars* franchise begins with the transformation of the existing game world. Set 250 years after events in the Eye of the North expansion, the continent of Tyria is central to the user experience with advances in technology creating a new attitude among its inhabitants and pushing the gameplay in a fresh direction.

Visually the world has changed too, with Tyria's cities and landscapes dented through war and natural disasters, and scorched by the rise of the five Elder Dragons. A heavily modified version of ArenaNet's powerhouse of a game engine looks set to make Tyria a world ripe for exploration yet fraught with danger from its magic-casting, weapon-wielding inhabitants.

> **“GUILD WARS 2 *FEELS MUCH MORE LIKE YOU'RE ON A BIG ADVENTURE RATHER THAN A SERIES OF NPC-GIVING QUESTS”***

Having no choice but to adapt to the changing environment, the game's five playable races are united against the Elder Dragons yet separated by their individual needs and goals. While the goblin-like Asura have been forced out of their subterranean dwelling, the savage Charr legions crank up their war machines in preparation for battle.

The shape-shifting Norn are now shacked up in the dwarven ruins of the Shiverpeaks, while a mysterious sentient race known as the Sylvari have only recently been born into this brave new world yet understand its power more than most.

The humans, now governed by a hereditary monarchy, are under more threat than ever yet hold strong in Divinity's Reach and plan to use the new technology and brute determination to protect their Queen from ill harm.

These races, and their subsequent story arcs, are the beating heart of *Guild Wars 2*, helping to create a personal role-playing experience that can be tailored and sculpted on the pathway to the inevitable battle against the Elder Dragons.

Dynamic events – a big departure from the rigid quest-giving system of the previous game – add to that unique individual experience with multiple outcomes, while furnishing players with choice and reward for exploring the persistent online world.

“We've tried to remove the barriers between you being a hero and having adventures in the game world,” explains Lead Designer Eric Flannum. “Guild Wars 2 *feels much more like you're on a big adventure rather than a series of NPC-giving quests.”*

The formulaic MMO structure is broken down further with the new levelling system, which acts as a progress marker in *Guild Wars 2* rather than a set of points that you consistently feel you need to reach.

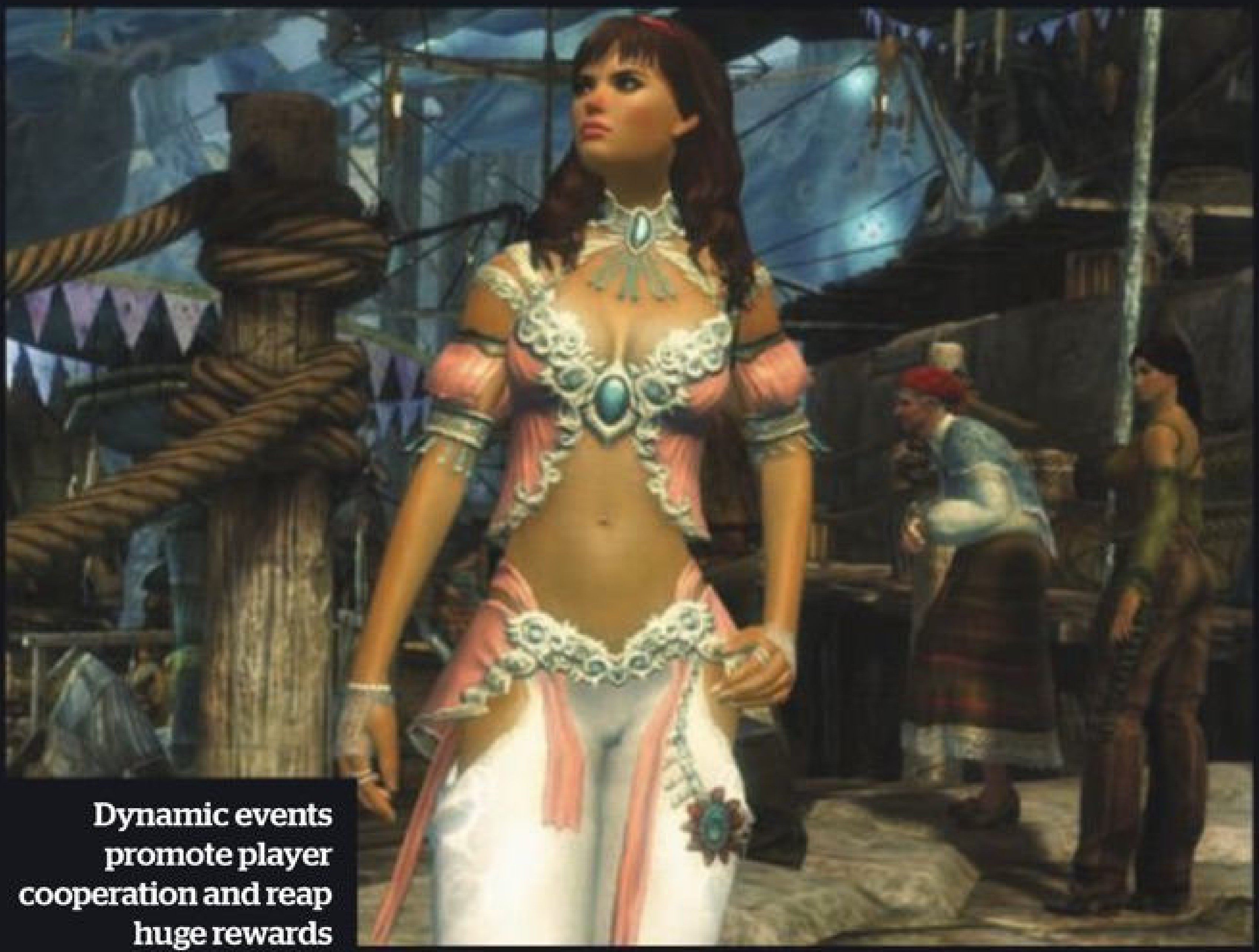
“What we wanted to do was to have lots of different ways to progress your character because we recognised that there are different things that motivate different players and there's a lot of different sorts of play styles out there,” says Eric, referring to the abundance of activities that players can involve themselves in, from crafting in various disciplines to harvesting the world for precious materials.

This fresh approach to the genre also surfaces in the revised combat system, a hybrid between the hot-key combat scheme of the first game and a more action-orientated skill-based system. *“In* Guild Wars 2 *we tried to keep that tactical choice system but to make it much more action-orientated without requiring a ton of twitch skills,”* says Eric.

Away from the highly personable PvE experience, *Guild Wars 2* offers a persistent online world sure to be brimming with other like-minded adventurers. Continuing its rich tradition in pickup and competitive PvP, the large-scale battles offer players a variety of roles with ▸

Even *Guild Wars 2*'s smaller dragons are formidable opponents

Visceral, dynamic and visually impressive, the new skills system is easy to learn and rewarding to master



Dynamic events promote player cooperation and reap huge rewards

With five races to choose from, players can shape their character and tailor the experience

▸ rich rewards for success that should keep them coming back for more. With all players starting on a level playing field, it's shaping up to be the perfect playground for team-orientated novices and experts alike.

The breadth of choice in *Guild Wars 2* and the promise of a personal role-playing experience are just a couple of reasons why NCsoft's MMO looks set to stand out among its peers. *Guild Wars 2* is also subscription free, meaning no additional monthly fees. With five races to choose from, as well as a comprehensive set of professions to master and a vast array of skills to learn, the stunning world of Tyria is well placed once more to encapsulate players in its dramatic, magical world.

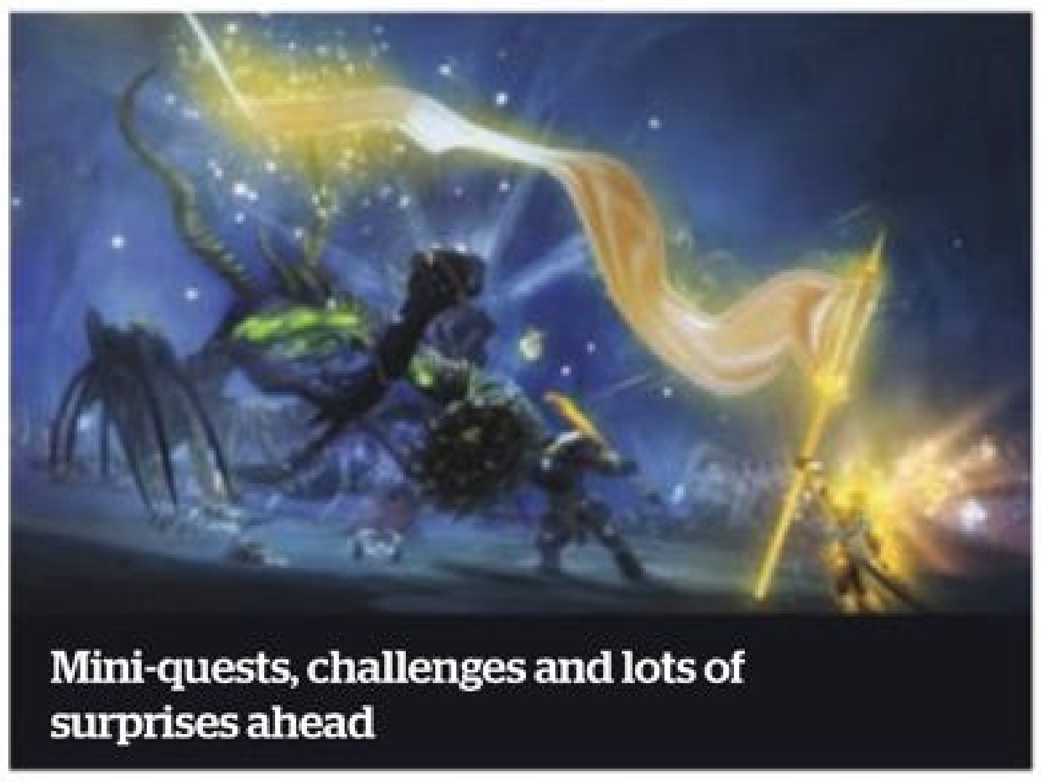
SPACE PIRATES GO WILD IN INTERGALACTIC MMO

NCsoft is also busy working alongside its California-based Carbine Studios on *WildStar*, a free-to-play intergalactic MMORPG with a striking stylised aesthetic of majestic forests, towering mountains and murky swamps.

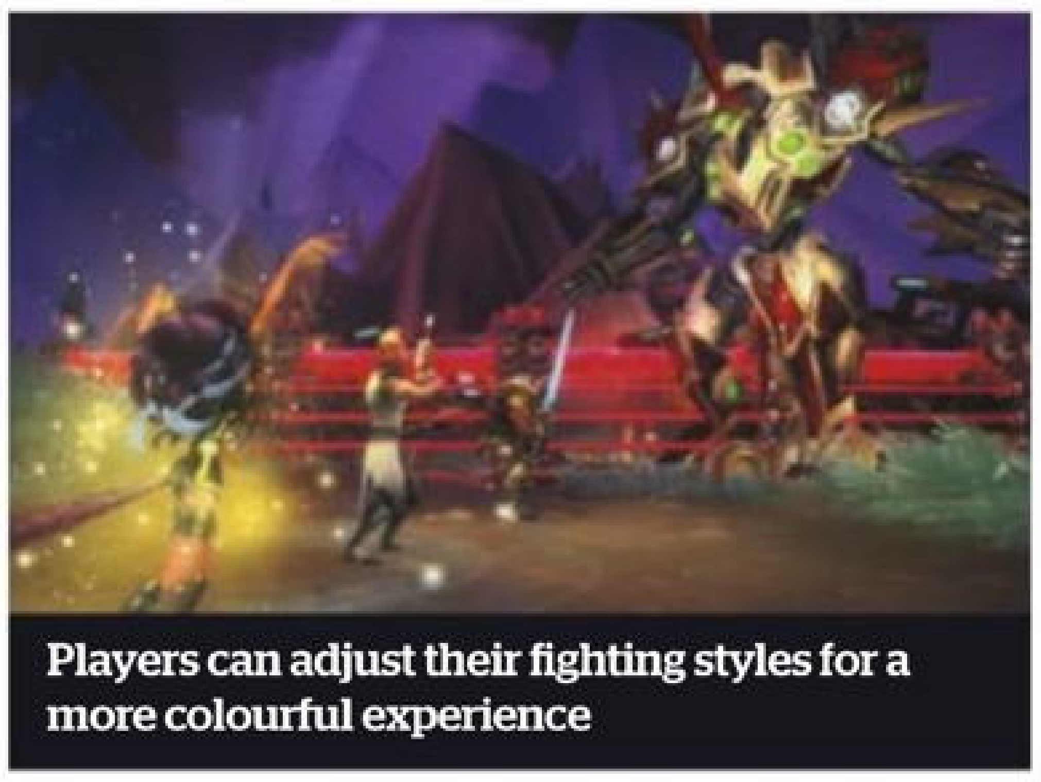
Featuring a chaotic mix of different races from all corners of the galaxy, *WildStar* promises fast-paced action, coupled with a rewarding path system and an innovative 'Momentum' mechanic with layered quest areas that cater for different playstyles.

Staple MMORPG ingredients, such as crafting and PvP play, will also be present, but it's *WildStar*'s unique take on the class system where Carbine looks to innovate, with four very distinct roles to choose from allowing players to explore, conquer, collect or build.

No release date as yet, but with four years already in the making expect this personality-soaked sci-fi MMORPG to make an appearance sometime in the very near future.



Mini-quests, challenges and lots of surprises ahead



Players can adjust their fighting styles for a more colourful experience

Social connectivity via cross-platform play is a major focus for all future games

INNOGAMES

THE PIONEER OF FREE-TO-PLAY BROWSER-BASED GAMES PLANS TO MOVE INTO THE NEW ERA OF GAMING WITH STYLE

It's no coincidence that InnoGames has become one of the world's biggest developers of browser-based games in the increasingly popular free-to-play (F2P) space.

While many MMO makers have long relied on subscription-based models to bring in revenue, the Hamburg-based developer set up its first 'Freemium' game in 2003 with a long-term strategy to keep its customers fully-engaged with core gaming experiences that reap rewards in the long term.

"You don't have to download anything so our games are instantly accessible," says InnoGames' Chief Marketing Officer, Volker Dressel. *"Our games are aimed at core gamers who will spend hours upon hours playing our titles.*

The key to success for us is the high quality of our games. Our browser-based titles have given those people who have only ever tried casual games the chance to enjoy an in-depth gaming experience and assess the quality before buying items to enrich their experience."

Tribal Wars

With *Tribal Wars*, InnoGames created an MMORTS that engaged players from the outset, and in turn the community rewarded it by buying virtual goods to tailor their experience. The success of *Tribal Wars*, which is still played today by millions, gave the studio the platform it needed to become an industry leader with about 80 million registered players now engaged in its diverse range of titles.

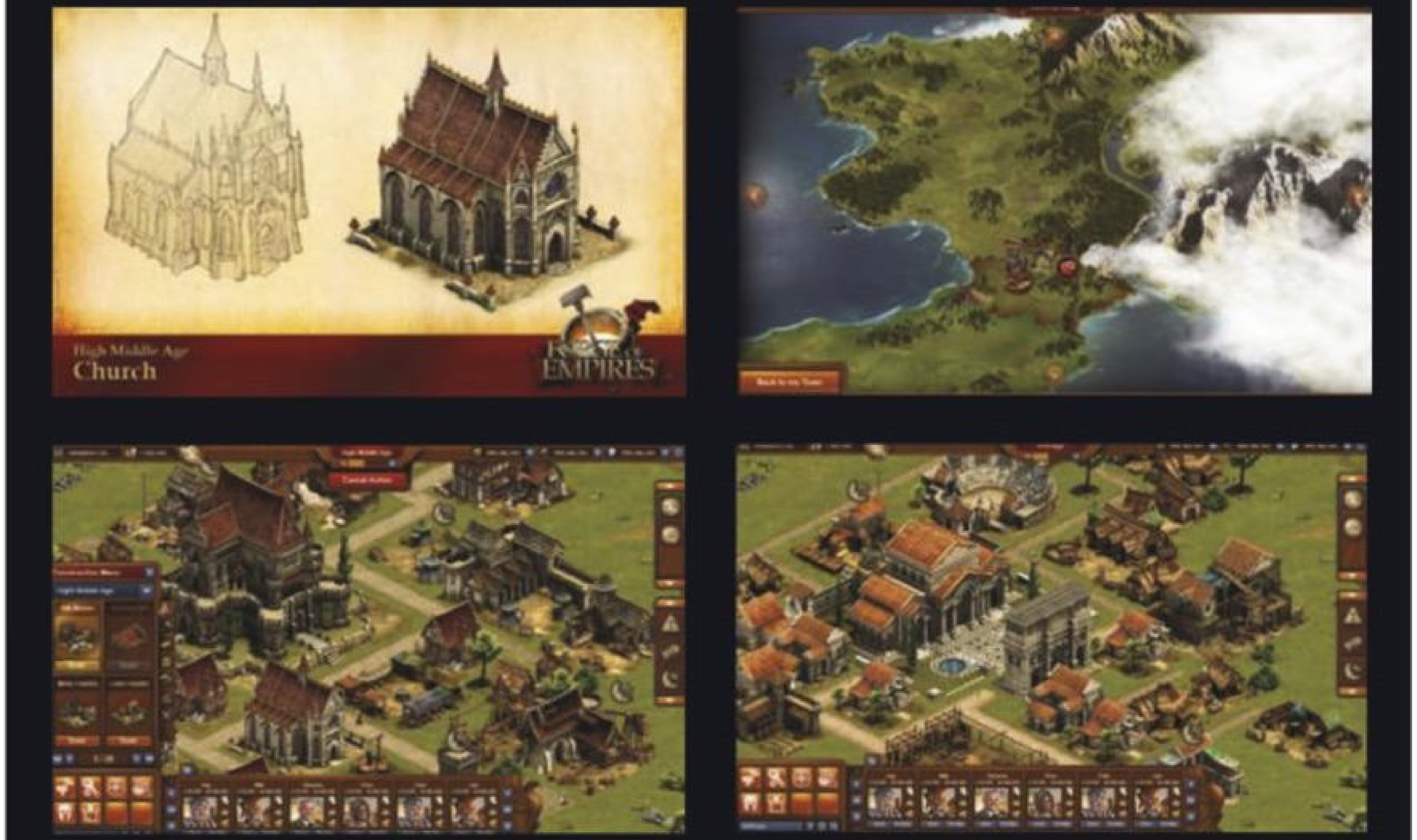
The value of offering a range of accessible experiences that don't require a powerhouse of a PC to play but still have the necessary depth to engage users has paid off for InnoGames, which has evolved alongside its community and created a portfolio of games that consistently entertain. With a range of quality virtual goods available at affordable prices across all its titles, it's a business model that it believes can only lead to more success in the future.

"Adopting the free-to-play model has worked extremely well for us," says Volker. *"Though some players don't ever spend money on in-game services or goods, many millions of players from around the world enjoy tailoring their experience so it soon adds up. The revenues will continue to be substantial in the future."*

INNOGAMES PLANS TO OFFICIALLY RELEASE ITS FIRST PUBLISHED TITLE IN THE COMING MONTHS

InnoGames has built its vast empire by understanding gamers' needs

InnoGames' long-term strategy continues with the release of *Forge of Empires*, an in-depth city-building MMO that gives players the chance to build a vast empire, resource manage and battle in PvP tournaments. The focus on a solid single-player experience and the inclusion of a robust multiplayer component looks to have impressed, with glowing reports from the community on its current beta phase.



Creating core gaming experiences without the need for software downloads

Forge of Empires will be accompanied by *Lagoonia*, a socially-focused MMORPG experience that takes place on a desert island. *Lagoonia* will offer a totally different experience, centred on relationships between characters and social interaction on an island where players will be encouraged to create a paradise haven.

A more chilled-out MMO with a focus on social interaction

Looking ahead

Also active as a publisher, InnoGames plans to officially release its first published title in the coming months. This game will be another example of the diverse range of titles that the company prides itself on backing and an indication of its intention to forge relationships with developers in and outside of Europe.

Looking ahead, InnoGames plans to invest in emerging cross-platform technologies and will be at the forefront of this exciting new phase. This is an area where the studio believes there will be tremendous growth moving forward into this new era. *"Cross-platform gaming will be the standard,"* says Volker. *"The behaviour of people is changing and browser-based games will give everyone the chance to play one title across every device whether they're sitting on the sofa, on the train or in the office."*

Every game currently in development at the German studio will be available as a cross-platform title and accessible to all, says the company. And it's that desire to make a real connection with gamers and give them the luxury of interacting across multiple devices that looks set to cement its future in the industry.

Other developers are beginning to see the value of core game experiences using the F2P business model. As more and more gamers dip their toes into 'Freemium' waters, subscription-based titles like *Lord Of The Rings Online* have switched to F2P to bring more players to its servers before its creators ask them for cash. It's a very wise move, and a business plan that has propelled InnoGames to the lofty position of one of the industry's most successful game studios.

NEXT GEN ONLINE GAMING – MADE IN GERMANY

HOW THE GAMEFORGE GROUP IS SHAPING THE FUTURE OF GAMING

Germany-based Gameforge is a pioneer of online gaming. Starting life as a bunch of game enthusiasts developing browser games in 2003, the company has carved out its own niche in a growing market that has exploded into the mainstream.

Meanwhile it also offers a spectrum of hugely popular client-based online roleplaying games such as *Metin 2* or *4Story* as a publisher. Unlike conventional online games publishers, Gameforge offered its game worlds for free from the very beginning. Players didn't need to pay any retail price or subscription fees anymore. Due to free and convenient access, players registered in masses for games like *OGame*, *Ikariam* or *Metin 2* and populated the virtual game worlds in their thousands. According to their own preferences, players could also decide to invest in certain comfort services or game items.

Helping to pioneer this free-to-play business model, Gameforge now has a portfolio of over 20 games, with 300 million globally registered players and a growing staff roster of 600 employees. With a firm focus on long term success, Gameforge has taken over Berlin-based MMO publisher Frogster during the course of 2011, which had also enjoyed massive growth with its focus on client-based virtual worlds for core gamers.

The integration of these two companies brings together their deep knowledge and experience in a range of areas, including development, publishing, IT, programming, PR, marketing, product and community management, as well as customer support. Combining forces has ensured that both are well prepared as competition in the sector increases. Both companies are situated in Germany, but are marketing their games throughout the whole of Europe, North America and emergent markets like South America and the Middle East. They are operating a massive server and network infrastructure and their own dedicated account management and payment systems to host thousands of players in their game worlds simultaneously around the clock.

Though both companies still work out of their original offices in different parts of Germany and under their own banner, the Gameforge group is firmly focused on continuing the good work in the fields that both parts have excelled in.

So, what does the future hold and what can you expect from the German online gaming veterans? In their headquarters in Berlin and Karlsruhe, the teams are working on several projects to further innovate online gaming for their players. Kicking off in February, the studio has teamed up with Korean-based NCsoft to release the free-to-play version of the popular fantasy MMORPG *Aion*, which has already received critical acclaim during its subscription-based life cycle. With the promise of major updates in the near future, *Aion* looks set to gain a new legion of fans.

SO, WHAT DOES THE FUTURE HOLD AND WHAT CAN YOU EXPECT FROM THE GERMAN ONLINE GAMING VETERANS?

***Eligium – The Chosen One* attracts players with features such as unique mounts to raise**

Standing tall and proud, Gameforge reaches the heart of its gaming communities

▸ Following close behind Aion will be *Eligium – The Chosen One*, a community-orientated, class-based, free-to-play MMO game complete with ranking systems, dungeon raids and guild wars. Featuring in-depth personal development options, as well as the ability to raise mounts, *Eligium* offers a broad range of quests and challenges that should satisfy the thirst of adventurers of all kinds.

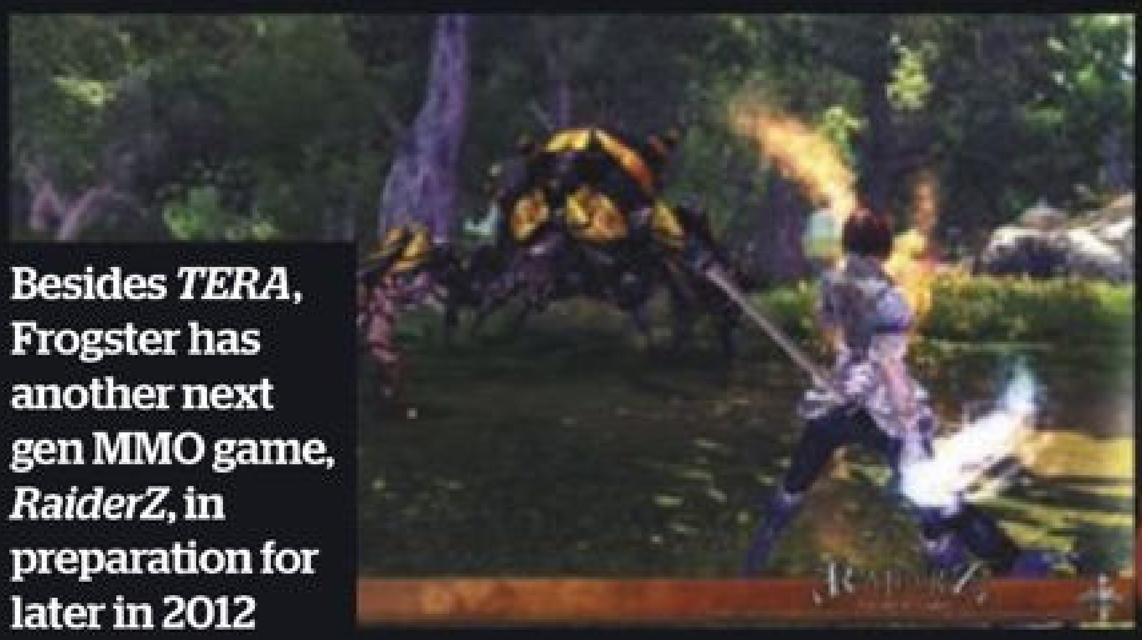
Next up is *TERA*, the highly anticipated Unreal Engine 3-powered subscription-based MMO game, which also lands in May. This next-generation 3D fantasy world boasts stunning graphics and animation, while its innovative real-time combat system opens up a new chapter of dynamic, action-oriented battles in online games. Strong pre-order sales of *TERA* suggest that there's still plenty of room for premium subscription-based MMO games in the future to complement the company's range of quality free-to-play titles.

Further plans for the year include a major new update from Frogster for its popular MMO game, *Runes Of Magic*, which has become one of the most successful client-based titles in the western world. Chapter V will arrive later this year with a host of new content. Capitalising on cloud computing technology developed by Dutch company Kalydo, both Gameforge and Frogster have recently released browser versions of *Runes of Magic* and *4Story* that no longer require time-consuming software downloads, but still offer the complete version of the game without any constraints. It's a signal of the company's intention to move with the times and be at the forefront of this emerging technology.

Inspired by the hugely popular *Monster Hunter* series, Frogster will also release another next-generation MMO game in the second half of this year. *RaiderZ* features a highly dynamic monster-hunting adventure featuring massive battles against huge creatures, and a unique skill system that gives players hundreds of ways to shape their character.

Online gaming is definitely one of the dominating future trends. Many players see MMO games as parallel worlds where they can escape and spend time crafting, trading or fighting, building, farming or growing plants. They offer a highly personable experience that many offline games can't – one that can be customised to suit the player's fantasies, with worlds that encourage interaction and offer adventures that capture the imagination.

With the experience of knowing what gamers want, and with intentions to expand into emerging markets, utilise cloud computing and embrace upcoming mobile and cross-platform technologies, the stage looks set for the Gameforge group as it plans to step into this new era of online gaming with a bang.



Besides *TERA*, Frogster has another next gen MMO game, *RaiderZ*, in preparation for later in 2012

Gameforge has offered the premium MMO game *Aion* for free since February 2012

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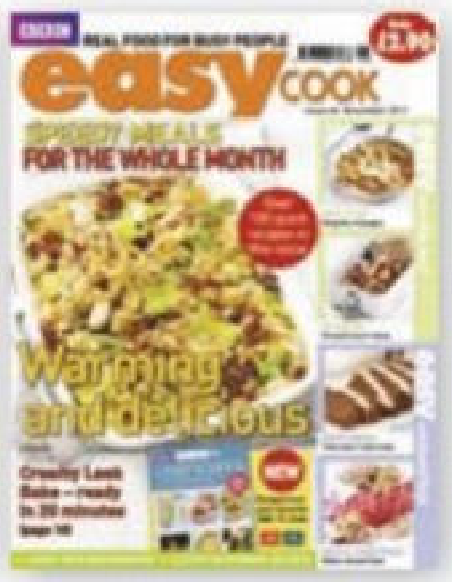

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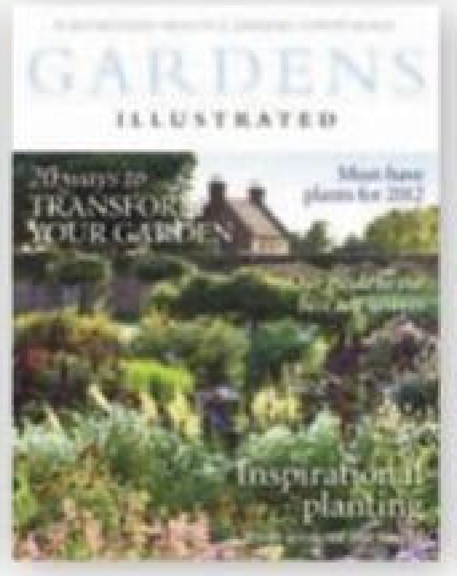

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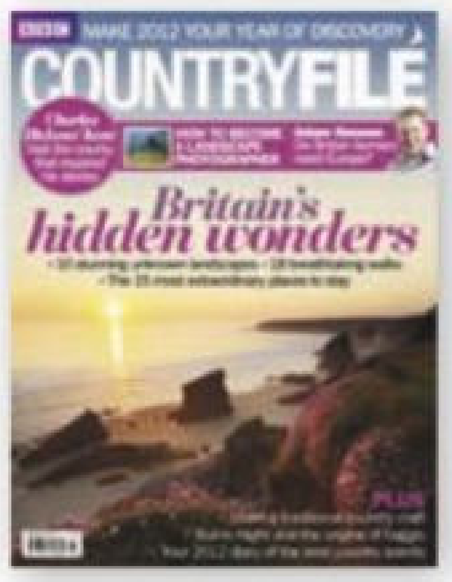

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Faster than the speed of light

Last year, physicists measuring the speed of neutrinos came up with a seemingly unbelievable result. **Edwin Cartlidge** looks at whether we're any closer to unravelling the mystery

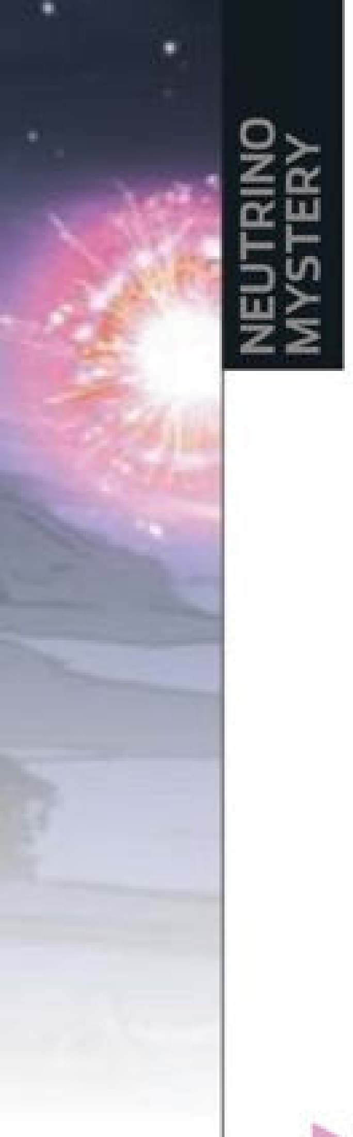
Under a mountain in central Italy, physicists at the Gran Sasso National Laboratory appear to have glimpsed a new view of the Universe. Using the OPERA particle detector, the scientists intercepted subatomic particles known as neutrinos, fired from the CERN lab in Switzerland. If their measurements are correct, the neutrinos did something extraordinary on their 730km (454 mile) trip across Europe: they arrived some 60 billionths of a second (nanoseconds) earlier than light would.

This result created a sensation when it was announced in September, because it seems to contradict Einstein's Special Theory of Relativity, which says nothing can travel faster than light in a vacuum. Relativity is a cornerstone of modern physics, and its demise could threaten our understanding of nature at its most fundamental level. At the very least, the existence of 'superluminal' (faster-than-light) neutrinos could point to the existence of extra dimensions beyond the familiar three of space and one of time.

Most physicists, however, think it's more likely that the OPERA team has made a mistake. There's no doubt the Italian researchers have been meticulous, precisely measuring the speeds of more than 15,000 neutrinos over three years, but it's also possible that their methods might have somehow introduced errors.

It may not be long before the issue is settled one way or the other. As *Focus* was going to press, physicists working on a similar experiment in the US were due to publish their own ▸

ILLUSTRATION BY CHRIS KING



▶ measurements of neutrino velocity. These measurements, they say, could be sensitive enough to confirm or reject the OPERA result.

The OPERA experiment is certainly pushing against a huge weight of evidence – both experimental and theoretical – in favour of Einstein's theory, and many scientists seem certain that the faster-than-light result will be rejected. In September, for instance, nuclear physicist Jim Al-Khalili of the University of Surrey said that if the faster-than-light result is confirmed, he would eat his own boxer shorts live on TV.

Even some members of OPERA don't accept the result. "It's ugly," says Dr Luca Stanco of the University of Padova. "It was completely unexpected and I am convinced there must be an error hidden somewhere."

A showdown with Einstein

Within a few months, OPERA itself should begin a new round of data collection. Stanco explains that, if the result withstands these extra tests, then physicists will need to build a whole new series of neutrino experiments and overhaul many of the theoretical models that have held for decades. "It would be like a tsunami in the world of physics," he says.

> *"It's ugly. It was completely unexpected and I'm convinced there must be an error"*

Special Relativity defies our commonsense notion of absolute space and time. Published by Einstein in 1905, the theory tells us that space and time are in fact relative to the motion of whoever measures them. A moving clock ticks more slowly than one at rest, for instance, and an object is shorter when in motion.

The theory also states that the faster a material object moves, the more mass it has. Since that mass would become infinite at light speed, no object can travel as fast as light can. On the other hand, particles of light – photons – can travel at maximum speed because they have no mass to begin with.

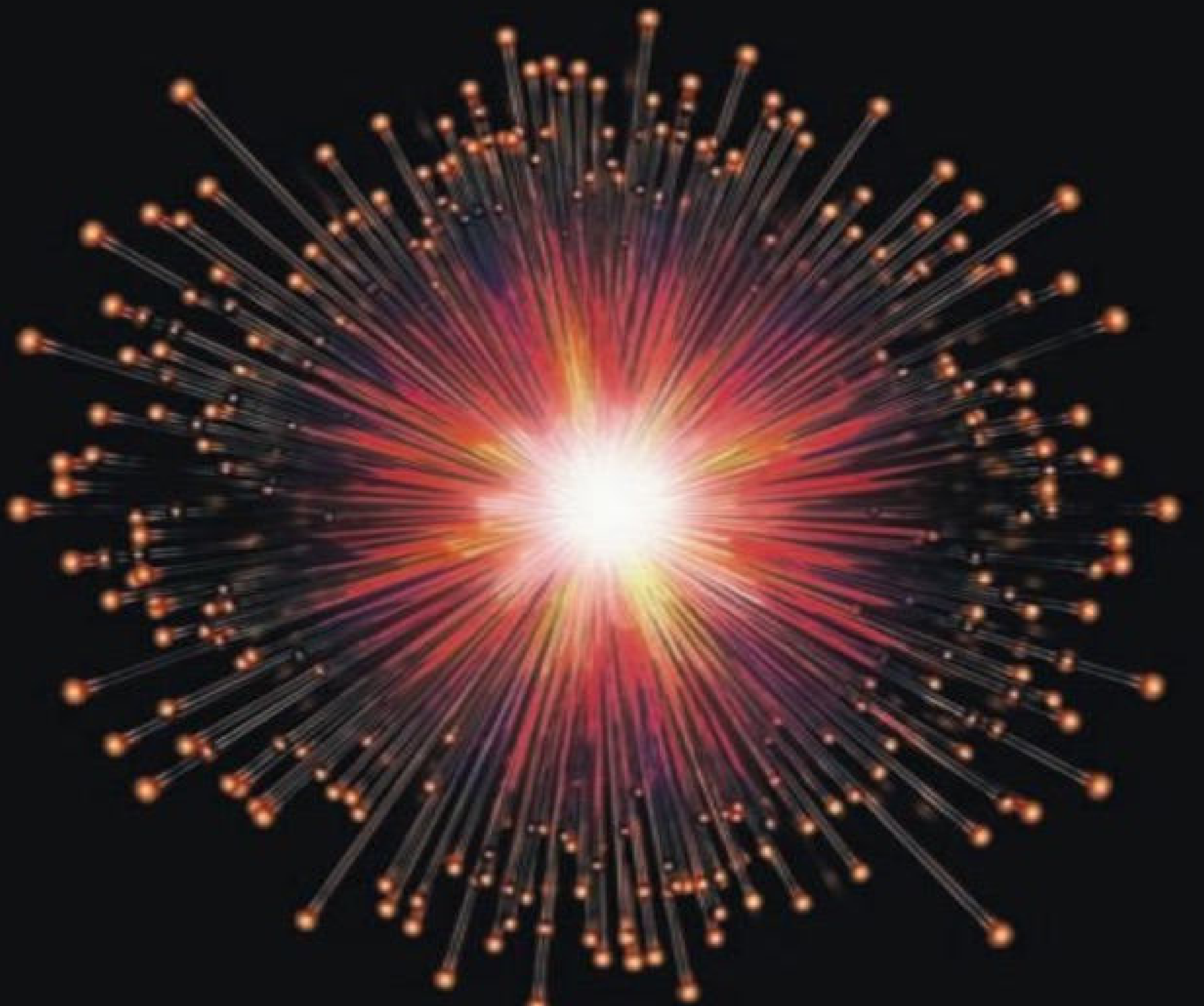
Einstein arrived at these strange conclusions by applying basic maths to two deceptively simple premises. These state that the laws of physics and the speed of light in a vacuum are the same for all observers, regardless of their speed or orientation. This constancy of the speed of light has since been put to the test in ever more precise experiments, and has never been found wanting.

A few physicists, however, believe that at even greater precisions they may start to see a chink in Einstein's armour. When we say that an object is moving, we mean that its position is changing relative to something else. Physicists call this something else a 'frame of reference'. For example, a passenger walks relative to a train, a train moves relative to the Earth, and the Earth moves relative to the Sun. Relativity assumes that there's no *absolute* frame of reference against which everything else moves; instead, everything is in motion relative to everything else.

Some scientists have tried to explain OPERA's extraordinary result by invoking the existence of one or more absolute frames of reference. In this case, Special Relativity would then no longer hold. Others have turned to the existence of extra dimensions, while still others suggest that perhaps neutrinos travel more quickly through

WHAT'S A NEUTRINO?

The *Focus* guide to the subatomic particle of the moment



Neutrinos are subatomic particles with no charge and almost no mass. They've been called 'ghost particles', because they interact so weakly with other kinds of matter: trillions of them pass through your body every second without leaving a trace. They are produced by nuclear reactions inside the Sun, and also when cosmic rays from deep space crash into the Earth's atmosphere.

Neutrinos come in three varieties, or 'flavours': electron, muon and tau. Although the OPERA experiment has now become famous for its faster-than-light measurements, it was in fact designed to study a phenomenon known as 'neutrino oscillation' – the transformation from one flavour of neutrino to another – which occurs as they travel through space.

If physicists find a difference in the way that neutrinos and anti-neutrinos (their antimatter counterparts) oscillate, it might shed light on why there's so much more matter in the Universe than antimatter, when equal amounts of matter and antimatter should have been created in the Big Bang. A difference in the behaviour of neutrinos and anti-neutrinos might explain the imbalance.

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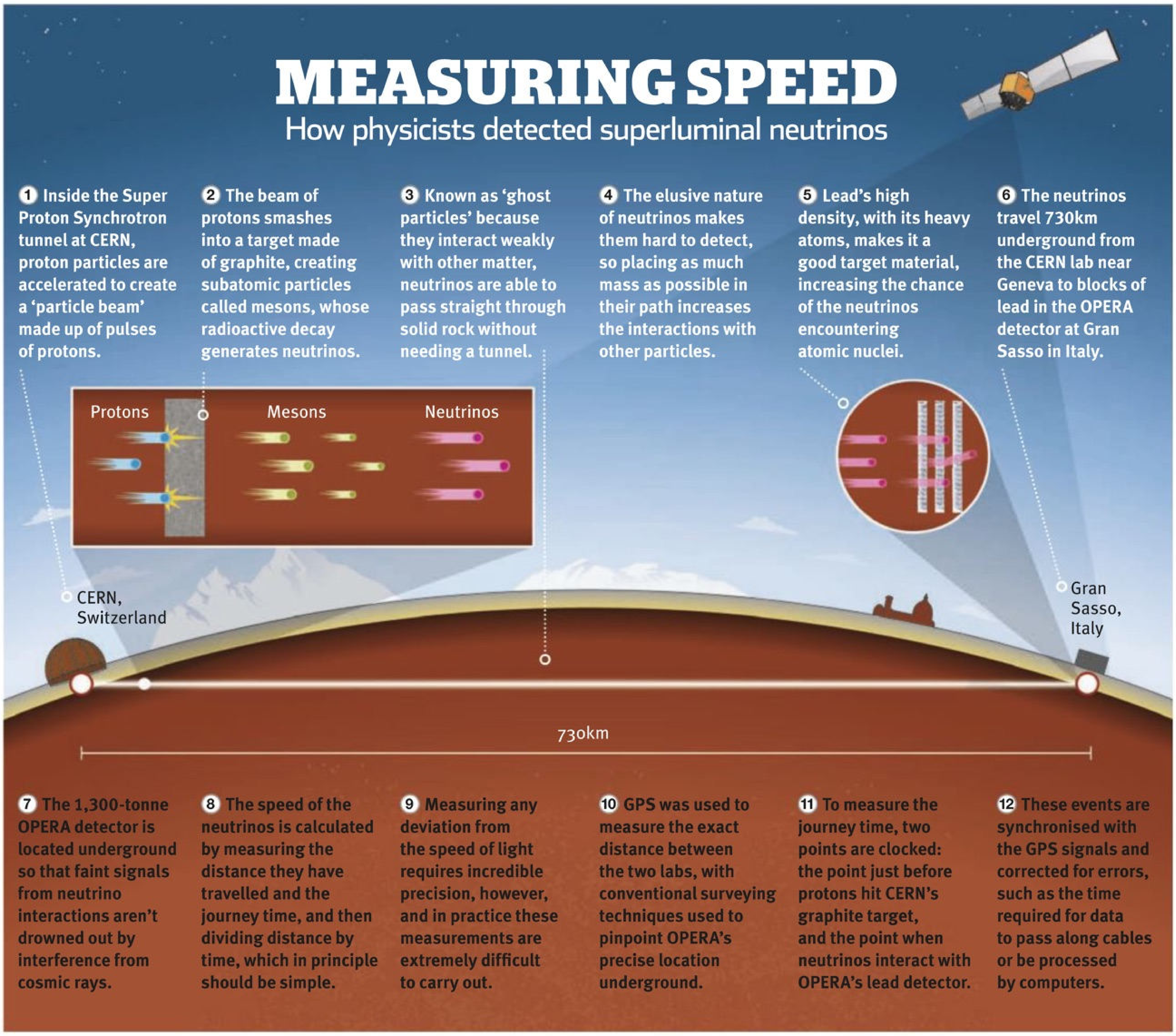
MEASURING SPEED

How physicists detected superluminal neutrinos



① Inside the Super Proton Synchrotron tunnel at CERN, proton particles are accelerated to create a 'particle beam' made up of pulses of protons.

② The beam of protons smashes into a target made of graphite, creating subatomic particles called mesons, whose radioactive decay generates neutrinos.

③ Known as 'ghost particles' because they interact weakly with other matter, neutrinos are able to pass straight through solid rock without needing a tunnel.

④ The elusive nature of neutrinos makes them hard to detect, so placing as much mass as possible in their path increases the interactions with other particles.

⑤ Lead's high density, with its heavy atoms, makes it a good target material, increasing the chance of the neutrinos encountering atomic nuclei.

⑥ The neutrinos travel 730km underground from the CERN lab near Geneva to blocks of lead in the OPERA detector at Gran Sasso in Italy.

⑦ The 1,300-tonne OPERA detector is located underground so that faint signals from neutrino interactions aren't drowned out by interference from cosmic rays.

⑧ The speed of the neutrinos is calculated by measuring the distance they have travelled and the journey time, and then dividing distance by time, which in principle should be simple.

⑨ Measuring any deviation from the speed of light requires incredible precision, however, and in practice these measurements are extremely difficult to carry out.

⑩ GPS was used to measure the exact distance between the two labs, with conventional surveying techniques used to pinpoint OPERA's precise location underground.

⑪ To measure the journey time, two points are clocked: the point just before protons hit CERN's graphite target, and the point when neutrinos interact with OPERA's lead detector.

⑫ These events are synchronised with the GPS signals and corrected for errors, such as the time required for data to pass along cables or be processed by computers.

something rather than nothing (see 'Shortcuts', p80).

But according to theoretical physicist Dr Giovanni Amelino-Camelia of the Sapienza University of Rome, no theory put forward so far has been able to explain the data. Several proposals could predict neutrinos arriving at the Gran Sasso lab before light does, but not by anything like as much as 60 nanoseconds. "It could be that theorists haven't found the right way to turn their ideas into mathematically consistent proposals," says Amelino-Camelia. "But the more time goes by, the more unlikely this seems."

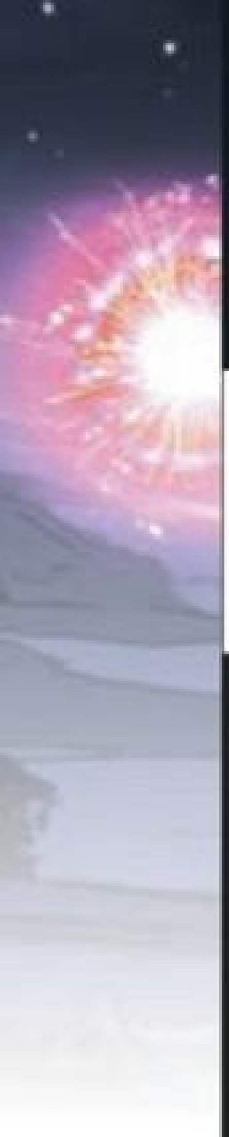
And it's not just exotic theory that doesn't square with the OPERA results. Andrew Cohen and Sheldon Glashow of Boston University have calculated that if neutrinos exceed light speed then they should lose energy by generating the equivalent of a sonic boom. The Italian experiment, however, hasn't recorded any such reduction in energy.

Then there's the problem of supernova SN 1987A. This stellar explosion took place over 180,000 years ago, but the light and neutrinos it generated arrived at almost the same time, in 1987. Had the neutrinos been travelling at the speed claimed by OPERA, they would instead have turned up four years earlier.

Sources of error

So if the OPERA researchers have made a mistake, where have they gone wrong? Critics initially thought they might have miscalculated the neutrinos' travel time, as the Italian team wasn't able to clock the moment at which individual particles started and finished their journeys, and instead used a complicated statistical analysis to find an average across all particles. This approach even worried some members of the OPERA team. These doubters argued that the analysis needed independent checking, and some refused to put their names to the paper announcing the result.

But according to Dr Dario Autiero of the University of Lyon in France, the physicist leading OPERA's data analysis, a second set of measurements completed in early November ▶



SHORTCUTS

ATTEMPTS TO EXPLAIN OPERA'S STRANGE RESULTS

FORCE FIELDS

One theory looks back to the 19th century notion of an 'ether'. This hypothetical substance was supposed to be the medium, present throughout the Universe, through which light ripples. Precise measurements of light have ruled out the ether's existence, but less tangible alternatives are still possible. According to the 'Standard Model Extension' theory developed by Alan Kostelecky of Indiana University, entities somewhat like force fields are sewn into the structure of space-time, in addition to the fundamental particles and forces described in the established Standard Model of physics. Each 'force field' would constitute a preferred direction in the Universe, or absolute frame of reference, and it might be that one of them interacts only with neutrinos – causing them to travel faster than light.

EXTRA DIMENSIONS

Some physicists believe that our 4D Universe (three dimensions of space and one of time) occupies a kind of membrane, or 'brane'. Reduced to a 2D picture, this brane would resemble the surface of a sphere, with extra dimensions existing inside the sphere. Neutrinos travelling from one point on the surface to another could take a shortcut through the extra dimensions, travelling a shorter distance than they would otherwise. In this way, the neutrinos wouldn't actually be travelling faster than light, they'd just appear to. But such extra-dimensional travel wouldn't work for the kinds of neutrino detected by OPERA. For this to happen, these ordinary neutrinos would have to morph into hypothetical 'sterile neutrinos'. Unfortunately, these sterile neutrinos wouldn't interact with other matter at all, so would be impossible to observe directly.

SPEED BOOSTS

Another option is that neutrinos travel more quickly through matter than through a vacuum, where they're limited to speeds below that of light. We already know that charged particles can move faster than light through a medium such as water, because the medium slows down both, but has a greater effect on the light. It's possible that in certain circumstances, particles such as neutrinos might actually get a speed boost when travelling through a medium. This explanation could explain the apparent conflict between the superluminal neutrinos observed by OPERA and the neutrinos emitted by supernova SN 1987A, which arrived on Earth at the same time as light. Neutrinos from the supernova didn't exceed Einstein's speed limit, and this might simply be because they were travelling through a vacuum (empty space) and not rock.

The Super Proton Synchrotron (SPS) tunnel at CERN – the source of the controversial neutrinos

▸ overcame this problem. Neutrinos detected at Gran Sasso are created from a beam of protons at CERN in Switzerland (see 'Measuring speed', p79), and by having CERN split the beam up into very short bunches, the OPERA researchers were effectively able to track individual particles.

Splitting the beam gave exactly the same result: the neutrinos still appeared to arrive at Gran Sasso about 60 nanoseconds ahead of light (give or take 10 nanoseconds). With light travelling at 1.08 billion kilometres per hour, the superluminal neutrinos were around 27,000 km/h quicker.

Another weak point might be the use of the Global Positioning System (GPS) to synchronise timing between the CERN and Gran Sasso laboratories. This involves satellites sending the same time signals to antennas at both labs, and then using these signals to record both when the neutrinos were created, and when they were detected. The OPERA team estimates that this synchronises timing to within around two nanoseconds, though it's conceivable that they miscalculated the time it takes the GPS signals to travel from the antennas to the labs' computers. It's also possible that GPS itself isn't as accurate as claimed.

Some physicists within OPERA remain unhappy that not everything

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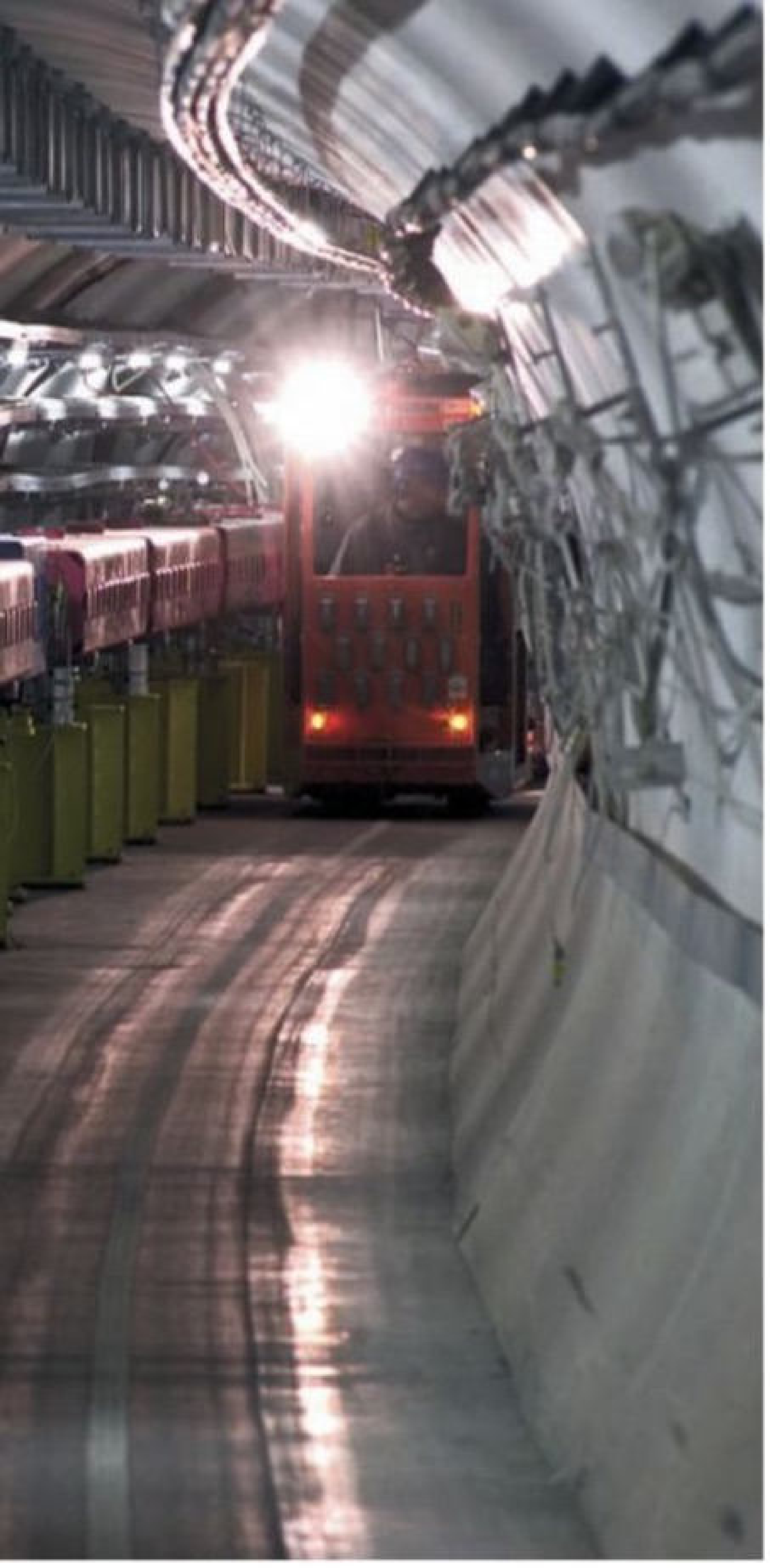

has been done to track down potential errors in the measurements. Autiero, however, is adamant. "We have no particular doubts because otherwise we wouldn't have published the results," he says. "There is no hint of an error that could have brought about this effect."

Autiero and his colleagues will nevertheless continue to search for any loopholes. In particular, they hope to use fibre-optic cables hundreds of kilometres long to cross-check the performance of their GPS. Then the group's third set of measurements, due to be completed by the summer, should be sensitive enough to correlate the neutrinos' journey time with their energy. Autiero says the data should also allow the velocity of neutrinos to be compared to the velocity of anti-neutrinos, giving the experiment more power to discriminate between competing theoretical models.

Differences aside, all physicists agree that the only way to settle the issue once and for all is through independent tests.

Suitable for MINOS

The experiment best placed to provide those tests is MINOS, which measures neutrinos sent 735km from Fermilab near Chicago to the Soudan mine in Minnesota. In fact, MINOS found a hint of superluminal neutrinos in 2007, but the experiment's sensitivity was far lower than that of the European effort.

MINOS spokesperson Jenny Thomas of University College London says that a new analysis of existing data was expected to be ready by February or March 2012, and that this analysis could be sensitive enough to confirm or reject OPERA's result.

> *"We can write beautiful symphonies, but we have to see if nature plays them"*

Professor Frank Close, a particle physicist at Oxford University, says it's important for scientists to keep an open mind – not assume OPERA is wrong simply because it appears to contradict Einstein. He uses a rather poetic musical analogy to describe how scientists explain the Universe through theory. "We can write beautiful symphonies," he says, "but we have to see if nature plays them."

Close points out that physicists have in the past made many important discoveries just by carrying out more precise measurements than anyone had been able to previously. Although it's possible that OPERA is in this category, says Close, he doubts it because there's simply too much experimental evidence and theoretical argument opposing it. "How many uncertainties could there still be buried in OPERA's measurement of time and distance?"

Giovanni Amelino-Camelia also remains doubtful. "I hope OPERA is right, and that it is telling us the weirdest thing possible. But I have to do my job, and that is being sceptical."

If neutrinos are indeed capable of faster-than-light speeds, then it would go against Einstein's theory of Special Relativity, and also imply that effect can precede cause: in other words, time travel should be possible.

But while Amelino-Camelia wouldn't entirely rule out such a possibility on the subatomic scale, he maintains that we should forget about sending large objects such as human beings backwards in time. So while the implications of the OPERA results remain unclear, don't start packing for that dinosaur safari or holiday in ancient Rome just yet. ■

Edwin Cartlidge is a science journalist based in Italy

Dr Dario Autiero hosts a seminar examining the OPERA results

FIND OUT MORE

http://bbc.in/R4neutrinos
BBC Radio 4 programme on neutrinos

http://j.mp/specialRT
Special Relativity explained at the website Einstein Online

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Q&A

Your questions answered

How is a memory formed? p86
Where does cosmic dust come from? p88
How do one-way mirrors work? p90
Do all animals have a brain? p92

How are light-years measured?

TAYO AJAYI, EMAIL

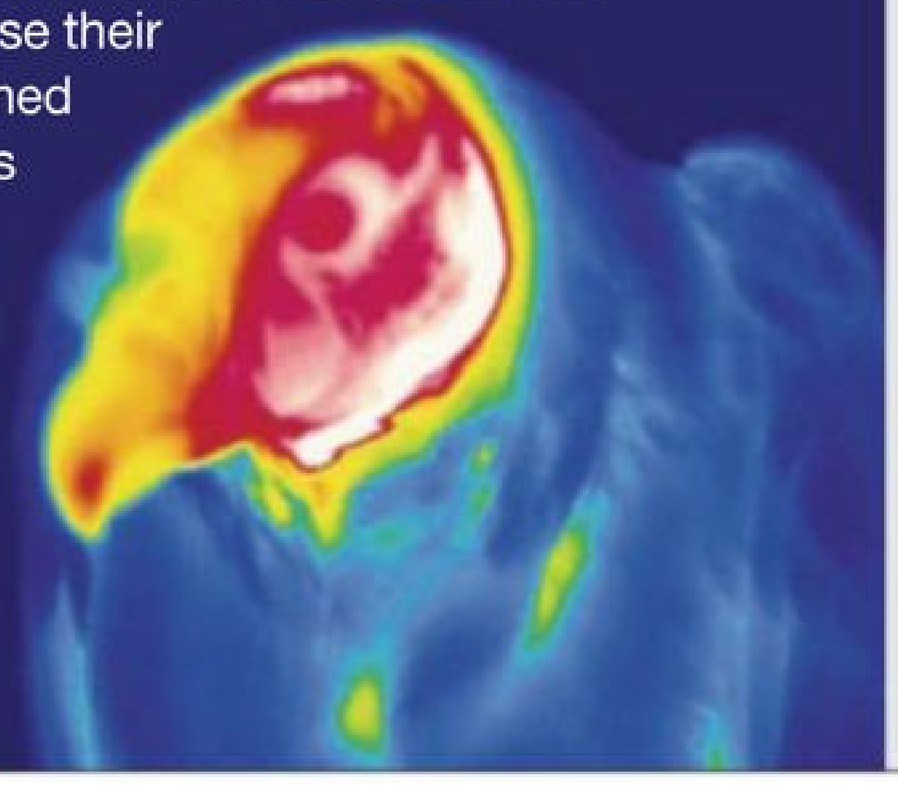
A light-year is the distance travelled by light in one year. It is commonly used as a unit of distance in astronomy. Astronomers use various methods to determine distances. Within the Solar System, distances can be found using radar, using simple trigonometry or by tracking orbital motions around the Sun. For relatively nearby stars, distances can be found by watching their tiny wobbling in the sky caused by the Earth's yearly journey around the Sun, or by analysing the orbits of binary stars. Further afield, direct distance measurements are not possible and astronomers resort to indirect methods.

These methods mostly involve objects called 'standard candles'. These are objects (stars, novae or supernovae, for example) for which the astronomer already knows the actual brightness. Comparing this with the brightness seen here on Earth reveals the object's distance. Since the Universe is expanding, the more distant an object, the faster it is moving away from us. So for really remote galaxies, astronomers estimate distance using a measure of the object's motion called its 'redshift'. **AG**

What is the hottest an animal can get?

MAUREEN MALLIA, MALTA, IPAD APP

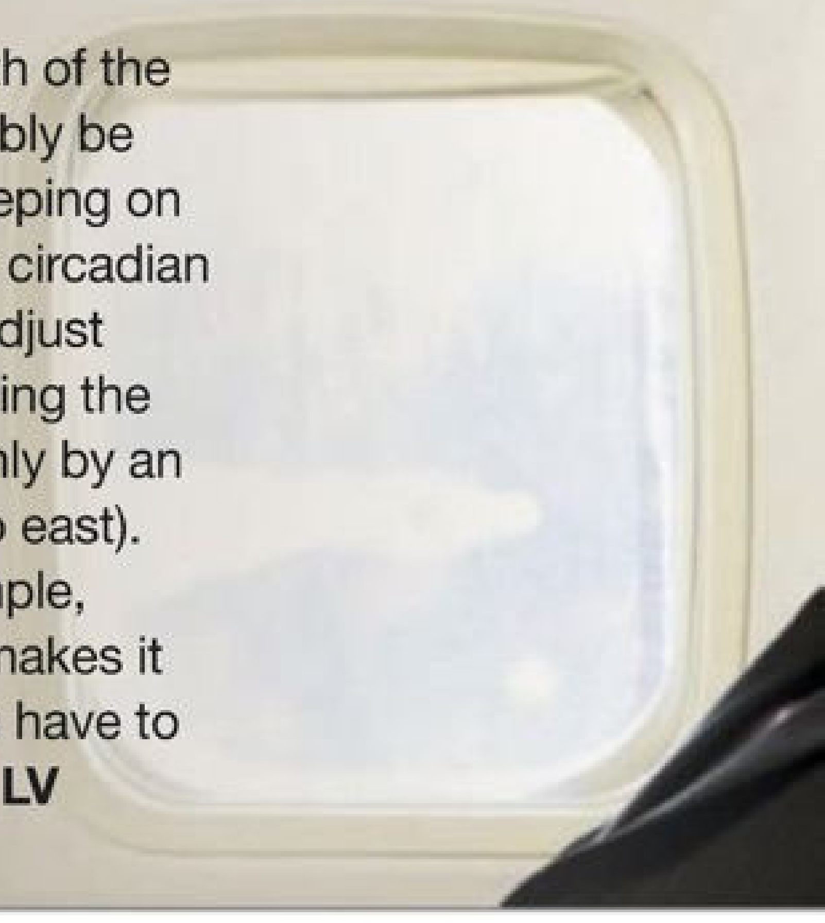
Normal body temperature for warm-blooded animals is between 36°C and 42°C, depending on the species. At 50°C, muscle tissue contracts spontaneously (known as heat rigor), which would be fatal if it happened to all your muscles simultaneously. But most animals will die before their body temperature reaches 45°C because at that point, enzymes begin to lose their effectiveness. The highest confirmed body temperature in a human was 46.5°C. Willie Jones of Atlanta, Georgia was found unconscious from heatstroke on the floor of his apartment in 1980, but survived after 24 days in hospital, albeit with some brain damage. **LV**



Why do you get more jet lagged when travelling west-east?

MARIANNE RIDLEY, KENT

It's partly because flying west extends the length of the day, so if you take off in daylight, you will probably be in daylight for the entire flight, which makes sleeping on the plane difficult. But it also has to do with our circadian rhythms. There is some evidence that we can adjust our body clocks by 90 minutes a day when setting the clocks back (travelling from east to west) but only by an hour a day when setting them forwards (west to east). Flights from Los Angeles to Heathrow, for example, often also take off in the late afternoon, which makes it mid-morning local time when you land – so you have to wait longer until a socially acceptable bedtime. **LV**



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Send us your questions

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How do solar sails create thrust?

MARTIJN DE VRIES, BRIGHTON

According to quantum theory, light comes in 'packets' of energy called photons. If they encounter an object placed in their way, they bounce off, pushing the object in the other direction. Using Einstein's theory of relativity, it's possible to work out the resulting pressure of the radiation pushing on the exposed area of the object. As one might expect, it isn't huge: at the Earth's distance from the Sun, it amounts to less than a billionth of an atmosphere. But this is where solar sails come in: by having a large surface area, they can capture enough of this feeble 'breeze' to produce useful amounts of thrust. The first successful use of solar sail technology came in 2010, when scientists in Japan launched Ikaros, an interplanetary probe propelled by a solar sail over 14 metres square. RM

DID YOU KNOW?

Hayden's bone-crushing dog (*Epicyon haydeni*) roamed the plains of north America 10 million years ago. Weighing up to 170kg, it was the largest species of wild dog so far discovered.

How does heat from the Sun reach Earth?

STEVEN WILLIAMS, SITTINGBOURNE

The Sun fuses 620 million tonnes of hydrogen into helium every second. Every time a helium nucleus is created, six photons are emitted. Photons are electromagnetic radiation and they can travel quite happily across the vacuum of space. When they hit Earth, they are absorbed by the atoms of the atmosphere or the ground surface and warm it up. **LV**

Q&A

The experts

SUSAN BLACKMORE
Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*

Alastair is a radio astronomer at Jodrell Bank Centre for Astrophysics

ROBERT MATTHEWS
After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University

GARETH MITCHELL
Starting out as a broadcast engineer, Gareth now writes and presents *Click* on the BBC World Service

LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach the Ground*

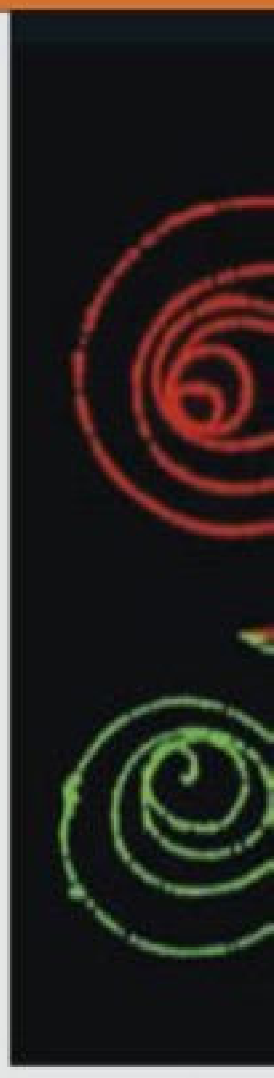
How is a memory formed?

ANDREW CIREL, EMAIL

☐ Call John again when Matt gets back (after 2/2) to arrange meeting
☐ Status of project tracking tool?
☐ Book flight to Sydney
☐ Look at PDA user manual

There is really no such thing as 'a memory'. Memory is a process, or set of inter-related processes, in which the brain changes in response to events. These changes then result in us being able to repeat a name or phone number (short-term memory), recall a specific event (episodic memory), recite a poem we learned at school (long-term verbal memory) or exercise a learned skill such as riding a bike or skateboarding (procedural memory).

Among the important mechanisms that underlie memory are changes to the strength of synapses (the gaps between nerve cells that signals have to cross), the growth of the tiny dendritic spines that grow out of the cells' branching dendrites, and many chemical changes that strengthen some networks of neurons at the expense of others. These changes occur all over the brain but some areas, such as the tiny hippocampus in the temporal lobe of the brain, are especially important. Damage here can mean a permanent loss of any ability to lay down new memories. SB



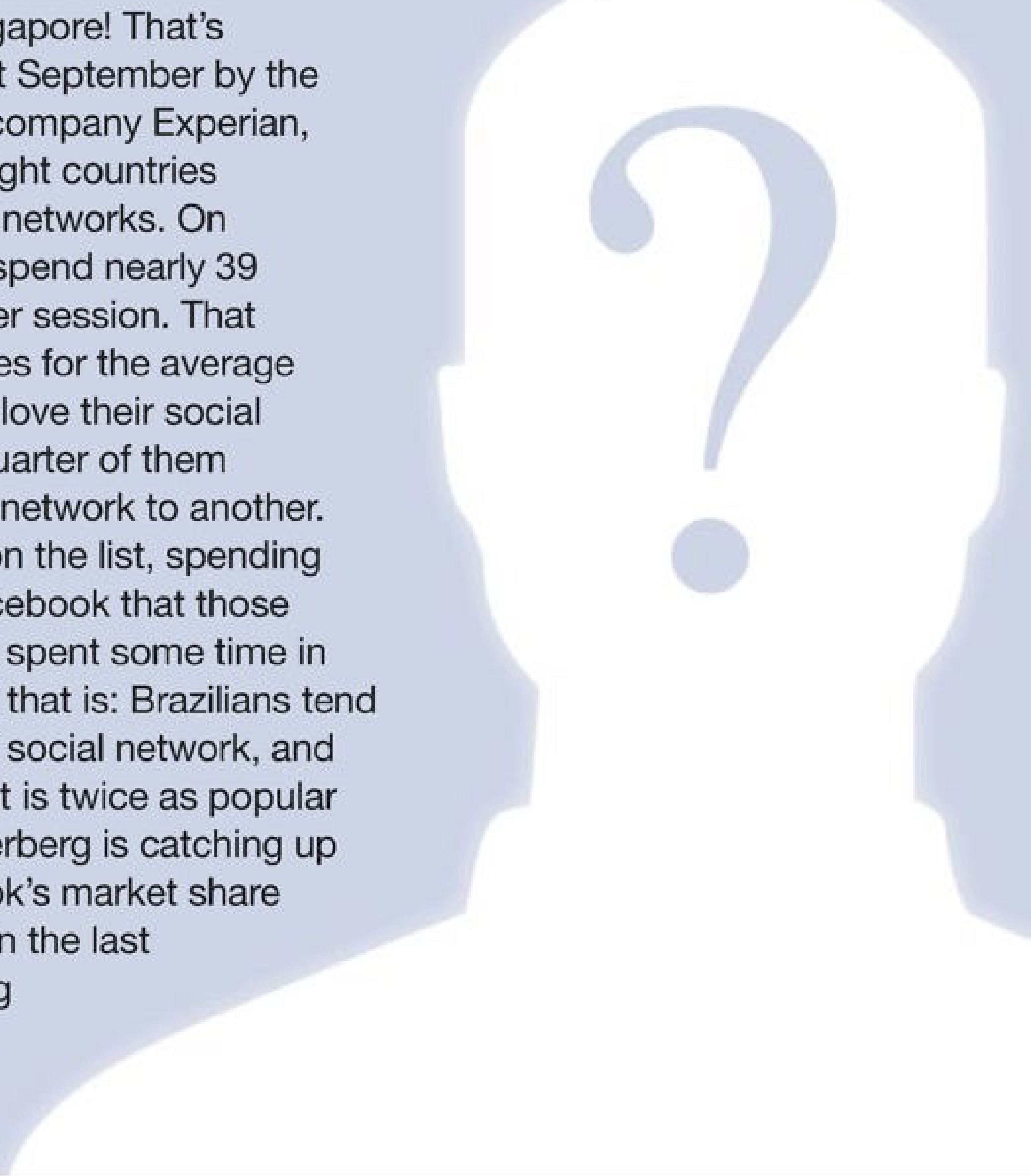
Why are repetitive noises so annoying?

MATTY TURNER, STOKE

They keep on attracting our attention and prevent us from concentrating on other things. We quickly habituate (stop reacting) to some repetitive sounds, especially regular ones such as ticking clocks, but not to others. Speed matters, with slowly dripping taps being especially maddening. The main reason is lack of control – if you know you can stop the noise at any time you will not find it annoying. **SB**

Which country spends the most time on Facebook?

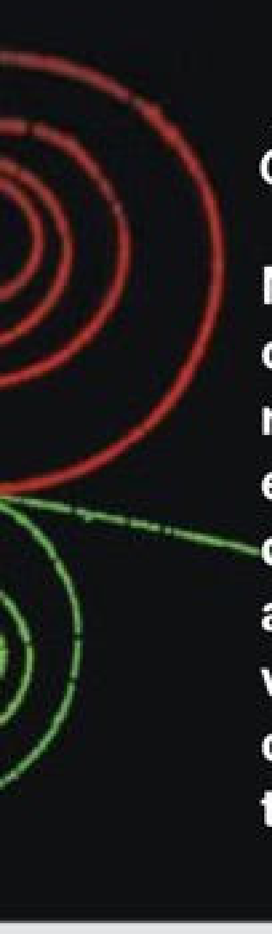
JULIA SWAIN, ALDEBURGH



And the winner is… Singapore! That's according to a study last September by the digital market research company Experian, which tracked the top eight countries spending time on social networks. On average, Singaporeans spend nearly 39 minutes on Facebook per session. That compares to 25.5 minutes for the average Brit. Users in Singapore love their social media so much that a quarter of them regularly jump from one network to another.

Brazilians are eighth on the list, spending only half the time on Facebook that those in Singapore do. Having spent some time in Brazil, I can tell you why that is: Brazilians tend to prefer Google's Orkut social network, and the figures confirm that it is twice as popular as Facebook. But Zuckerberg is catching up fast, increasing Facebook's market share in Brazil by 18 per cent in the last year. The fastest growing audience for Facebook is India. **GM**

THINKSTOCK X4, SCIENCE PHOTO LIBRARY, SUPERSTOCK



Why do matter and antimatter annihilate each other?

JUDITH STATT, EDINBURGH

Matter and antimatter are like mirror images of each other, having the same mass but reversed electric charge and other, more esoteric, properties. The laws of physics demand that when a particle and its antiparticle collide, the original particles must vanish – 'annihilate' – to be replaced with others having the same overall properties as the two particles combined. So if an electron and a positron – with their opposing charges – collide, they produce particles whose combined charge is zero. One common outcome is a burst of high-energy photons of gamma radiation with zero charge. But very violent collisions of electrons and positrons can produce pairs of more esoteric particles and anti-particles – which is what accelerators like the LHC do. RM

How much information is stored on my debit card?

KEVIN PRICE, COVENTRY

The chip on your debit/credit card is an EMV smart card, developed for EMVCo, the standards body owned jointly by MasterCard, Visa, American Express and JCB. Chip memory varies according to the issuer's needs, but the applications on the card need around 4KB of memory, leaving up to 16KB to store other data for processing transactions. The banks are rather cagey about what this encrypted data consists of, but it is *not* thought to include your date of birth or National Insurance number. **GM**

Is rail transport of goods more efficient than road?

JOHN CHESTER-PARSONS, EMAIL

Purely on a fuel-per-tonne-per-mile basis, rail transport is more efficient in almost every case. Trains travel on narrow rails with hard wheels. This reduces the contact area and almost eliminates flexing of the wheels, so the rolling resistance is about one-seventh that of rubber tyres on tarmac. Coupling wagons together allows a train to pull a very heavy load without increasing its cross-sectional area, so wind resistance is kept low. In contrast, if you try to couple more than two lorry wagons together, they become prone to fish-tailing.

Perhaps most importantly, trains travel on smooth, even tracks, without sharp bends, steep inclines or start-stop motion through heavy traffic. As a result, studies in the US have shown rail transport to be up to five times more fuel-efficient for comparable journeys.

However, rail infrastructure is much more capital-intensive than a road network, and the efficiency gains are much lower for light consumer goods than for bulk commodities like coal and iron ore. **LV**

DID YOU KNOW?

The only scientist to win both Nobel and Ig Nobel prizes is Russia's Andre Geim. In 2010 he was awarded the Nobel Prize for Physics for his work in developing graphene – 10 years after a project that levitated a frog using magnets had earned him an Ig Nobel, the annual prize awarded for 'improbable research'.

QUICKFIRE

Why do cats like boxes?

ELSPETH BLYTH, EMAIL

Because they feel warm and safe. Cats have few predators, but still prefer to sleep somewhere they cannot easily be seen. They use ambush tactics when hunting, and a box is a good place from which to spring out. They also seek warmth and cardboard, a good insulator, feels nice and warm to sit on. **SB**

How high can helicopters fly?

ADAM SOANES, SHERBORNE

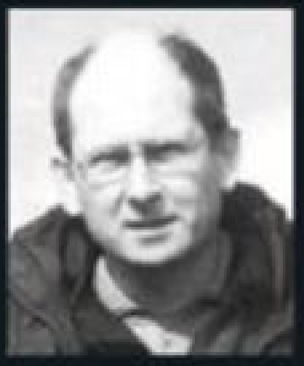
Helicopter flight at high altitudes is problematic, as rotors produce less lift than at lower levels where the air is thicker. Conventional engines also become inefficient, so gas turbines are used instead. Most helicopters can fly to about 5,000m, but in 2005, French pilot Didier Delsalle landed a helicopter on the summit of Mount Everest at 8,850m. **GM**

Are there any plans to build a space elevator?

PAUL BARNES, EMAIL

Several companies are purportedly planning construction of a 'space elevator', in which travel to and from space is by means of a cable anchored to Earth. However, the enormous technological challenges involved, as well as the huge cost, mean it is unlikely to happen any time soon. **AG**

WHAT IS THE **FUTURE OF...** Mythology?



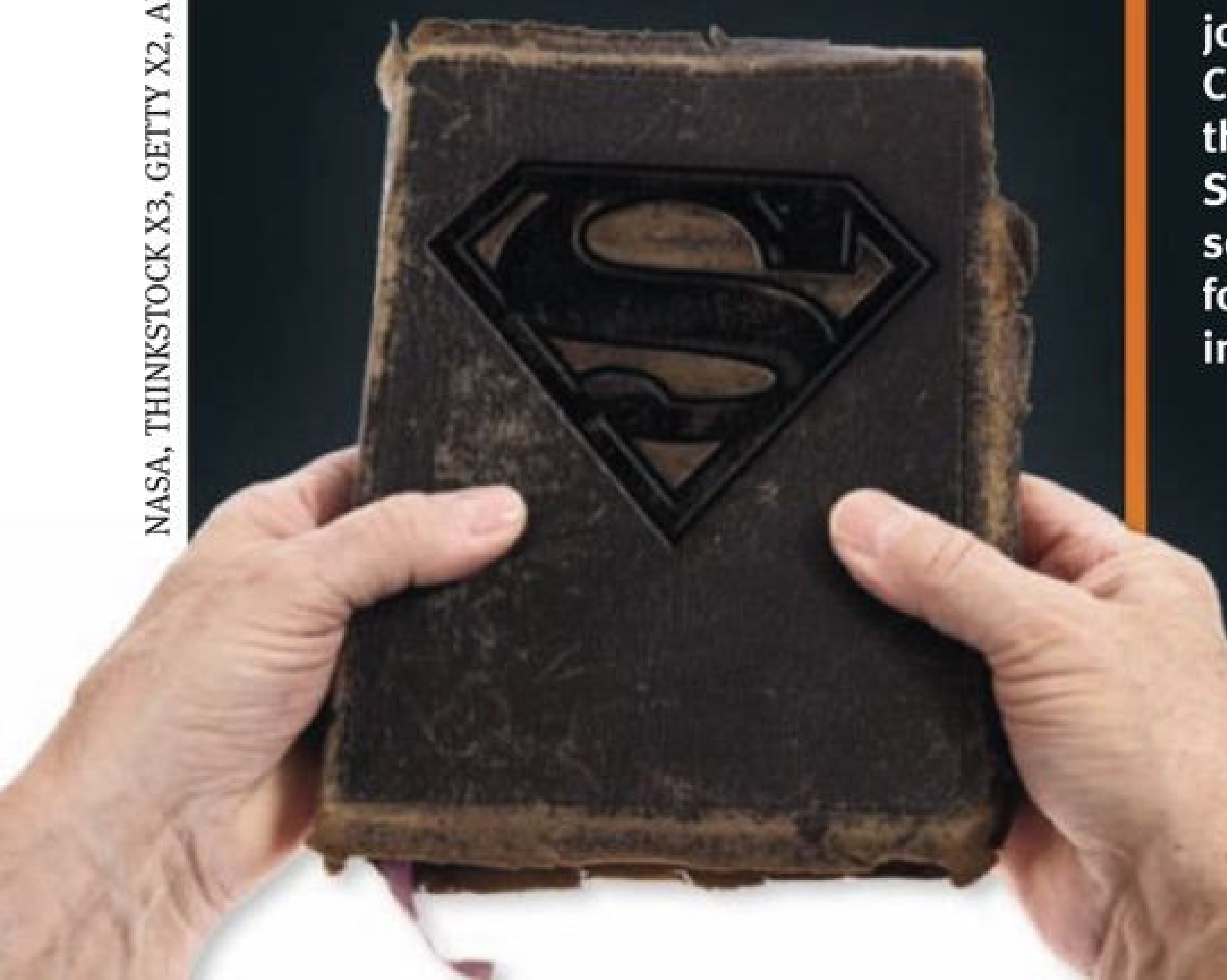
BY SF AUTHOR **STEPHEN BAXTER**

The historical record is woefully incomplete. Even the most familiar figures of the past were surely very different in person from their historical images. And some of our best-loved heroes, such as Robin Hood, never even existed. His legend stemmed from 14th century ballads, with elements like Maid Marian and Friar Tuck mostly invented in the post-medieval period.

More modern nations than England have confabulated heroes and heroines. In America, Davy Crockett was raised in the backwoods of Tennessee, but his hunting and Indian-fighting legend was developed during his own lifetime to boost his popularity in Congress. After he died, it was elaborated into a persisting folk epic.

Which of our modern myths and legends might turn into perceived 'truth' in the future? Great civilisations have fallen before, and an increasing proportion of our collective memory is stored in electronic form, vulnerable to instant destruction. New myths may sprout from faulty memories of our best stories: hobbits, Peter Pan, Sherlock Holmes, comic book heroes. Could our descendants ever 'forget' that these are works of fiction? After all, Robin Hood began life as a fictional character.

Perhaps in some atom-blasted future there will be a church based on the worship of a figure born on a doomed planet, who fell here as a child, lived in secret among us working miracles with his superpowers, and led us all to a better life. Perhaps the historians of that day, labouring in cathedrals adorned with a mighty golden 'S', will scratch their heads and wonder if such a place as Krypton ever existed.



NASA, THINKSTOCK X3, GETTY X2, ALAMY X4

Where does cosmic dust come from?

RASHID CHAKRAVORTY, BOLTON

In astronomy, the word 'dust' is often applied to any molecule or particle heavier than helium. However, the term more usually refers to the small, solid grains of material that permeate space, which often coalesce into clouds. These particles consist of all sorts of materials, from water and methane ice, silicates and carbonates, to complex organic molecules.

A major source of dust grains in interstellar space are stars that have evolved into the 'giant' phase. For example, silicate particles are found in the atmospheres of cool, oxygen-rich giants while silicon carbide is formed in the envelopes of cool, carbon-rich giants. More complex dust grains, including organic compounds, can be formed in the diffuse material surrounding stars. Supernovae explosions are crucial in scattering these particles into space, replenishing the dust clouds, which can go on to form new stars. **AG**

372.6

The fastest speed in km/h (that's 231.5 mph) ever recorded in Formula 1 racing. Juan Pablo Montaya of Colombia racked up this record-breaking speed during the 2005 Italian Grand Prix.

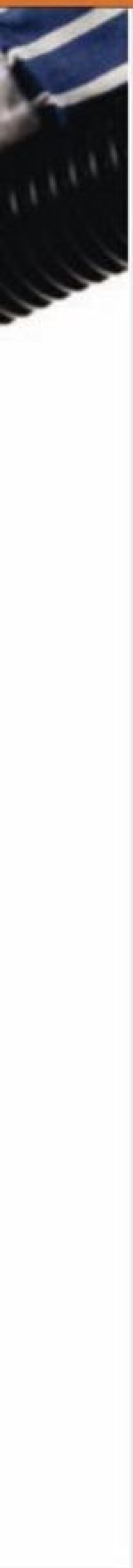
DID YOU KNOW?

On 5 April 2010, astronauts Naoko Yamazaki, Dorothy Metcalf-Lindenburger and Stephanie Wilson joined Tracey Caldwell Dyson on the International Space Station, setting a new record for the most women in orbit at any time.

Do rechargeable batteries die?

EMMA PETERS, BARNSLEY

Yes – usually after about 500 charge-discharge cycles. Lifetimes have improved though, especially for the lithium-ion batteries that now power most gadgets. Older NiCd batteries self-discharge more quickly and suffer from the 'memory effect', whereby they need to be fully run down once in a while to avoid conking out when only partially discharged. **GM**



Why do we say 'Ow!'?

MATTHEW PRICHARD, IPAD APP

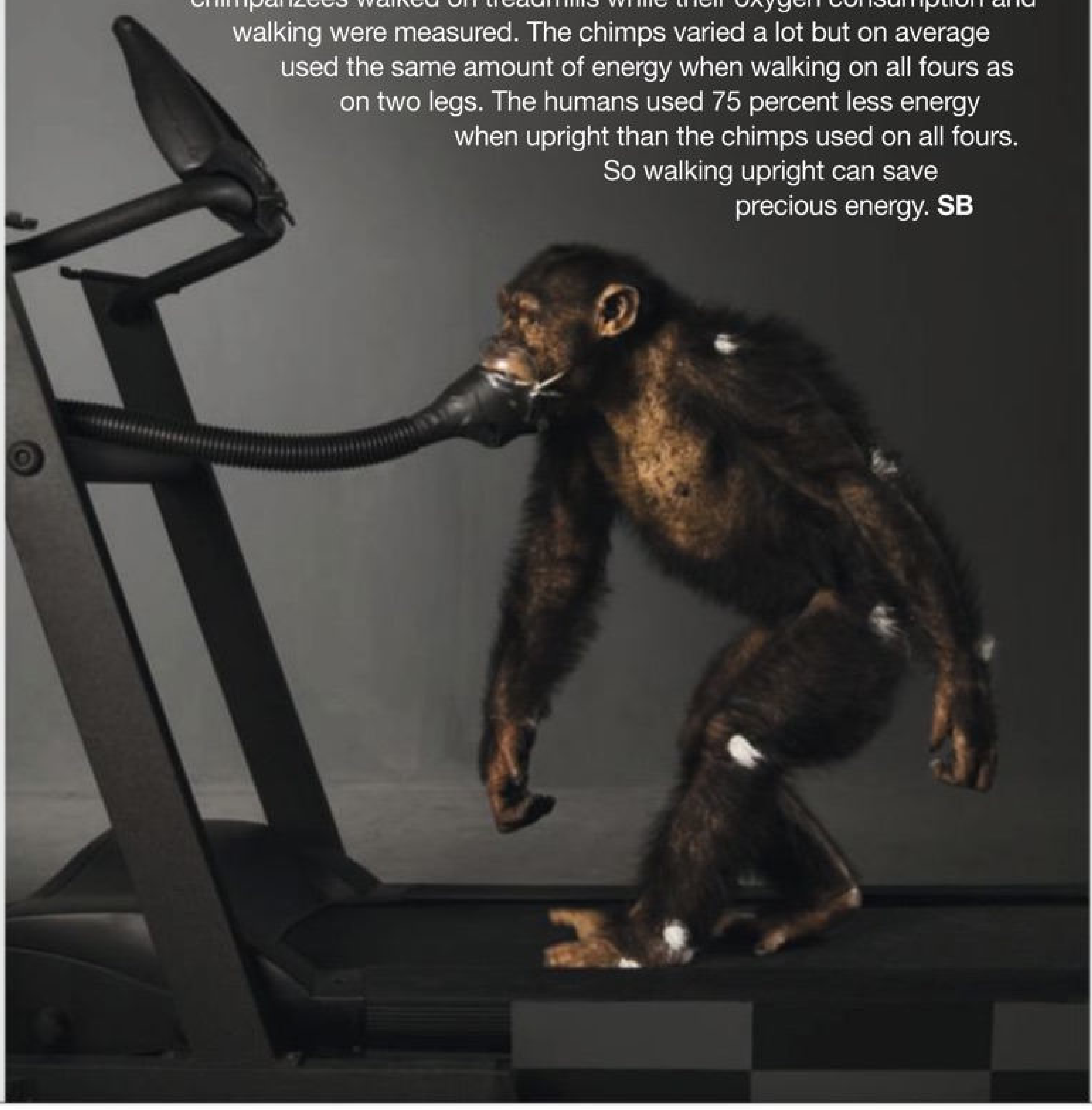
The semi-involuntary sound we make when we stub a toe or burn a finger is surprisingly constant across languages and cultures. The Spanish say 'Ay!', the Germans 'Ach!', the Chinese 'Aiya!', the Norwegians 'Au!'. In each case it's a wide-open mouth with a short breath. This is the fastest and simplest way to make a loud noise and it probably evolved as an alarm call to the tribe that danger was nearby. In case that danger is a wild animal, saying Ow also has the effect of baring your teeth threateningly. **LV**

Why do humans walk upright?

WILL BAIRD, SWINDON

Probably because it saves energy. The once popular idea that walking upright evolved to regulate body heat in hot weather has recently been knocked on the head by mathematical simulations that suggest there was insufficient evolutionary pressure for heat control to be the answer. Other popular theories include freeing our ancestors' hands for using tools or carrying food, and that walking upright makes it possible to wade through deeper water.

Most compelling, though, are experiments in which both humans and chimpanzees walked on treadmills while their oxygen consumption and walking were measured. The chimps varied a lot but on average used the same amount of energy when walking on all fours as on two legs. The humans used 75 percent less energy when upright than the chimps used on all fours. So walking upright can save precious energy. **SB**



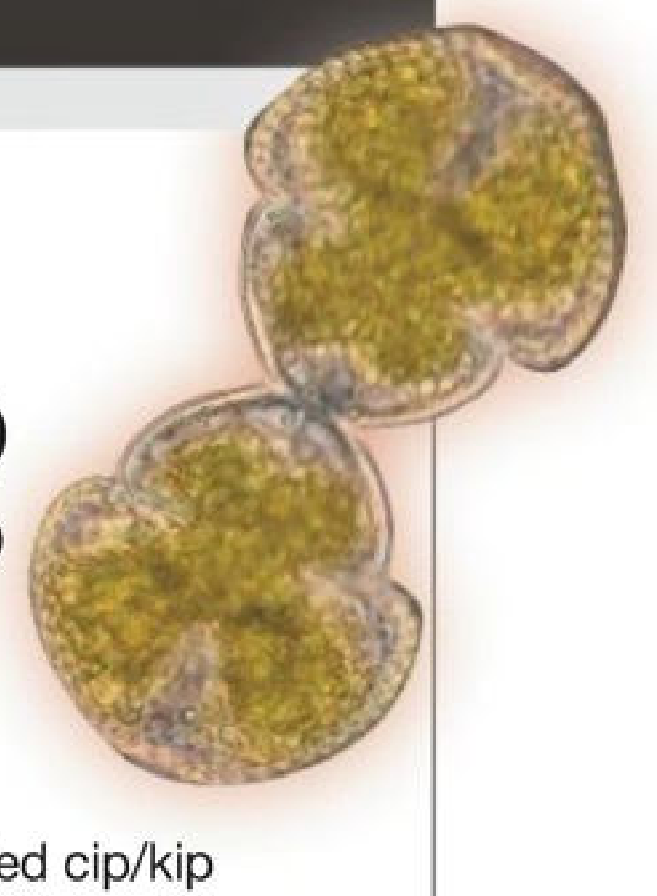
Does stirring a hot drink help to cool it down?

RICHARD O' NEILL, GLASGOW

Yes. Your hot cuppa loses heat through the sides of the cup and at the surface. Heat loss through the sides occurs because fast-moving drink molecules bump into the molecules of the cup and transfer some of their momentum, making the cup molecules vibrate faster. This vibration spreads through the cup, heating it up, and the cup in turn transfers this energy to the air around it by conduction and radiation.

At the surface of the drink, heat loss also occurs by evaporation. This is when some of the water molecules are moving fast enough to overcome the electrostatic bonds that attract them to each other, and so break free of the drink altogether. As they leave the liquid state, they take all their momentum with them, and because it's only the fastest molecules that evaporate, the average speed of the ones that remain drops rapidly. So the drink cools.

Stirring speeds up both mechanisms, by preventing cool boundary layers forming at the sides of the cup and by rotating all the drink molecules past the surface so that each has a chance to evaporate. Very rapid stirring also creates a concave shape at the surface, which increases the area available for evaporation. Finally, the spoon itself heats up, and takes some of the heat with it when removed. **LV**



How do cells know when to stop dividing?

PAUL O'CONNOR, NEWBURY

There are two main families of genes, called cip/kip and INK4a/ARF, that produce proteins which bind to, and inactivate, key proteins that trigger cell division. These inhibiting proteins hold the cell in a resting phase, so that the cell grows but does not divide. It can stay in this state for hours, weeks or years, until the inhibiting genes are themselves deactivated by pheromone signals from other cells in the body. **LV**

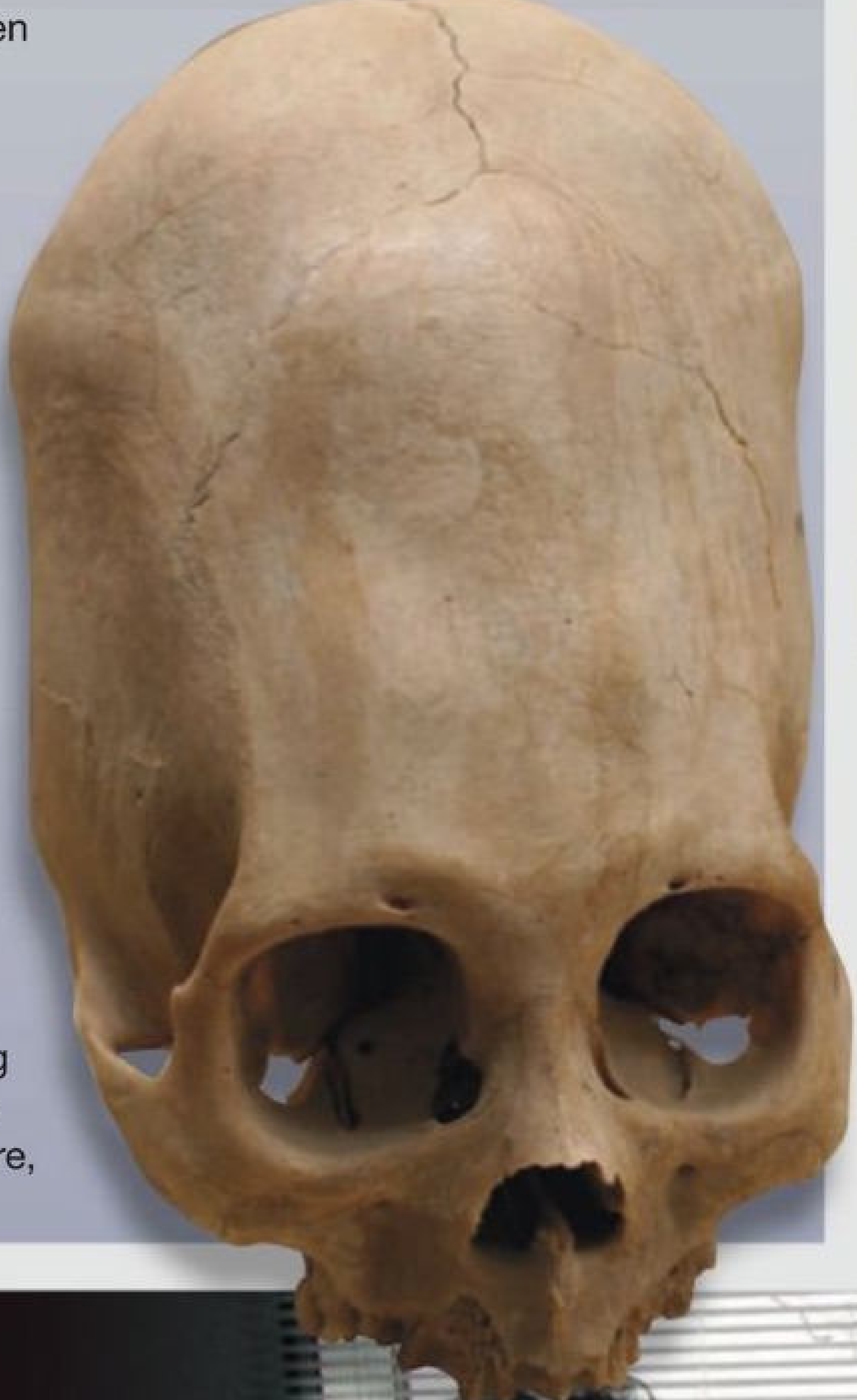
Does evolution always lead to bigger brains?

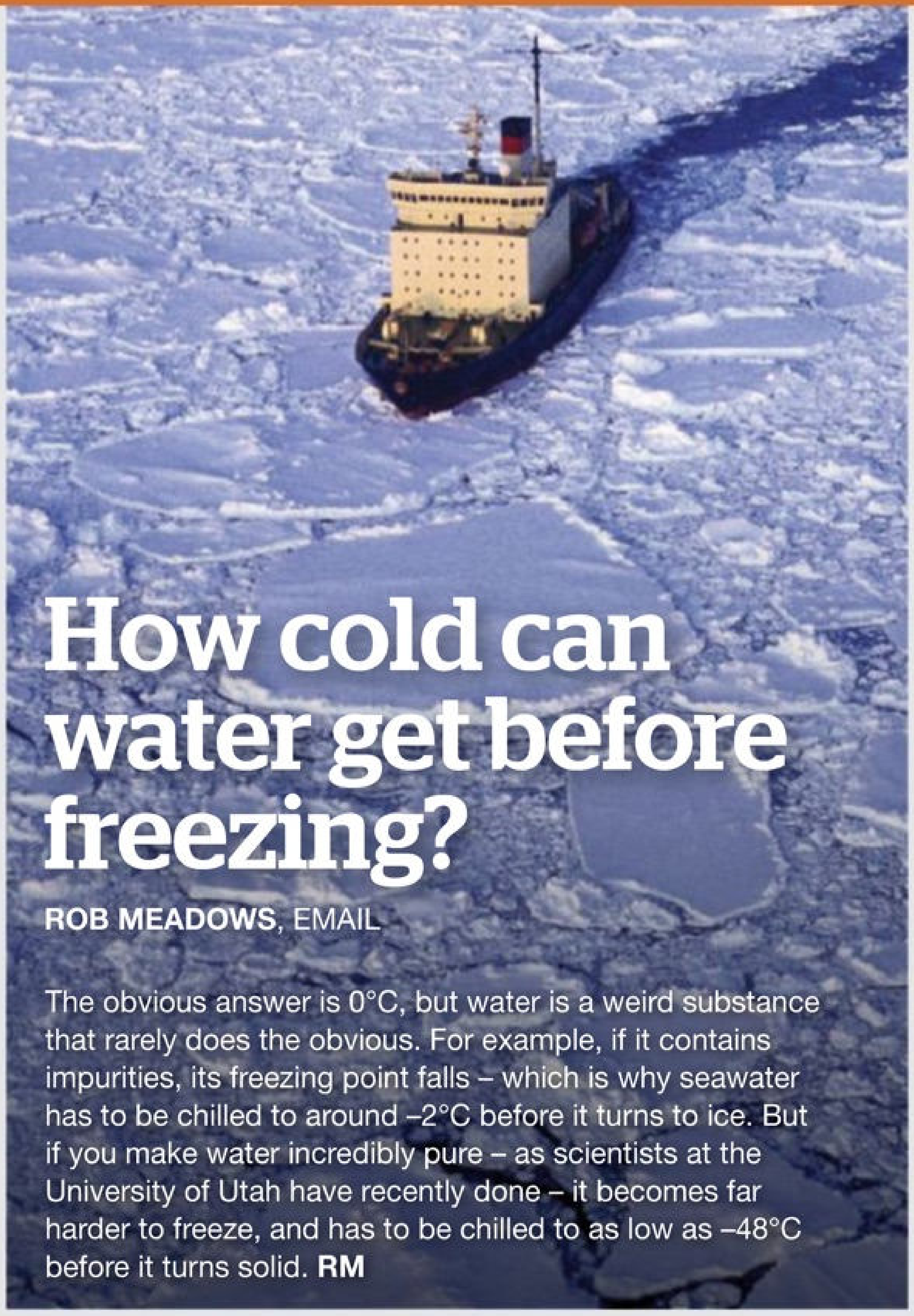
JO SMITH, DURHAM

No. Big brains are expensive, both to build during foetal development and to keep supplied with energy in adults. For example, when we are sitting at rest, our brain – which is only two per cent of our body's weight – uses about 20 per cent of our body's energy. This means that evolution will tend to produce big brains only when the benefits outweigh the costs.

There have been endless arguments about why humans developed such exceptionally big brains. My own theory is that once our ancestors began to imitate, they let loose a new evolutionary process based on memes and this drove their brains to become bigger and better at spreading even more memes. But most theorists believe they developed to provide better tool use, language or other kinds of intelligence.

What is known is that among primates, including monkeys, apes and lemurs, brains have sometimes increased in size and sometimes decreased. For example, brains grew smaller during the evolution of marmosets, mouse lemurs and mangabeys. What's more, brain and body size do not always evolve in the same direction. Gorillas grew greatly in body size without their brains growing correspondingly larger, while gibbons and colobus monkeys grew larger brains while their bodies grew smaller. **SB**





How cold can water get before freezing?

ROB MEADOWS, EMAIL

The obvious answer is 0°C, but water is a weird substance that rarely does the obvious. For example, if it contains impurities, its freezing point falls – which is why seawater has to be chilled to around –2°C before it turns to ice. But if you make water incredibly pure – as scientists at the University of Utah have recently done – it becomes far harder to freeze, and has to be chilled to as low as –48°C before it turns solid. **RM**

16,866

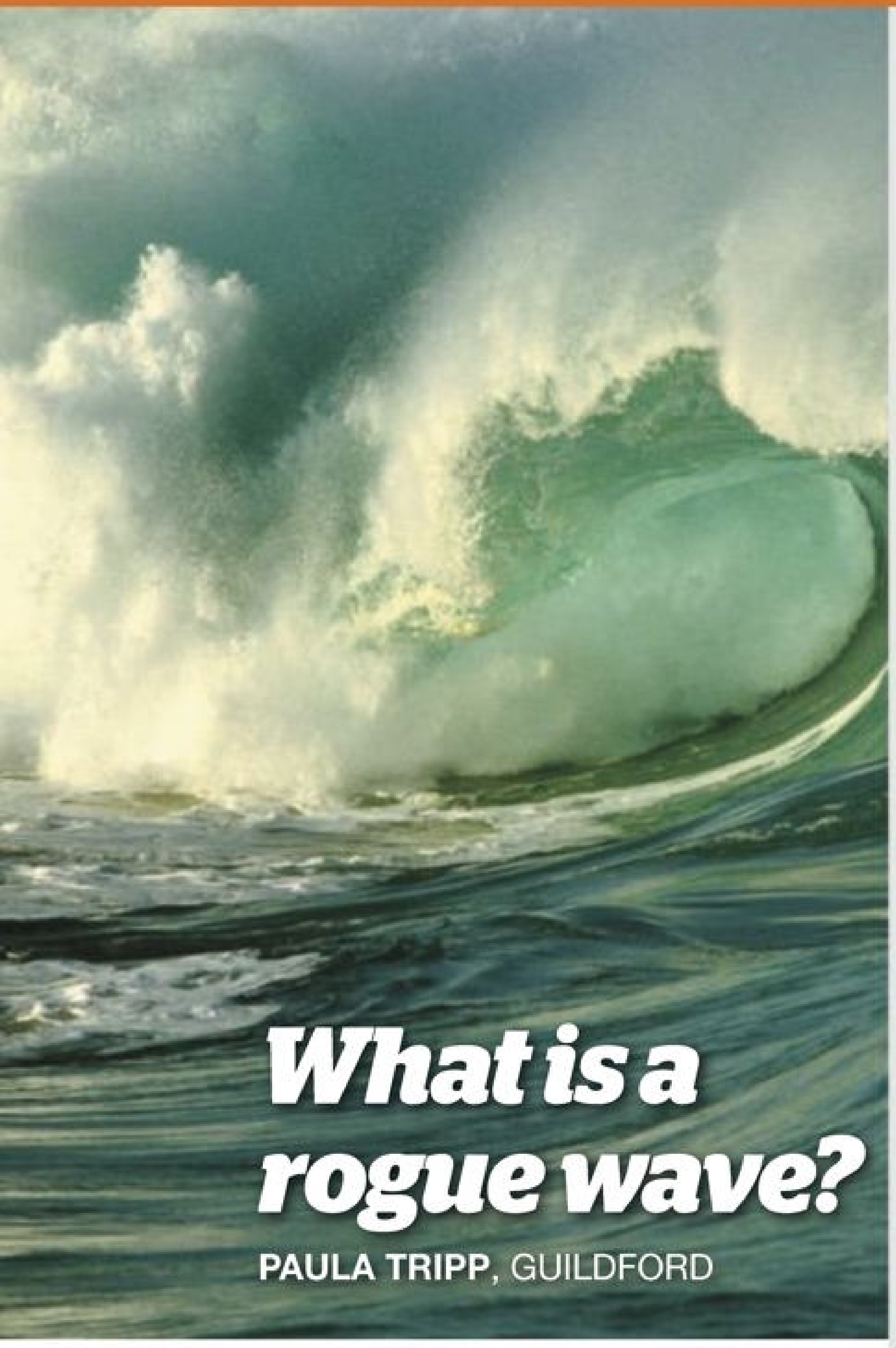
Number of protein-coding genes in the genome of a Monarch butterfly, recently sequenced by a team at University of Massachusetts Medical School

How do one-way mirrors work?

NEIL BULLEN, ST IVES

A one-way mirror allows people in one room to observe another via a window coated with a thin layer of reflective material. The trick lies in making this layer thin enough to see through, but thick enough to bounce back any bright light striking it. Then, by keeping the room under observation much brighter than the other, it's possible to look into it without being seen. **RM**

ALAMY, SUPERSTOCK X2, SCIENCE PHOTO LIBRARY, ILLUSTRATION BY PAUL WOOTTON



What is a rogue wave?

PAULA TRIPP, GUILDFORD

It's a wave that's twice as high as the highest waves normally seen under a given set of conditions. Rogue waves have been part of sailing folklore for centuries, but their existence was only proven in 1995 when a 25m wave was recorded in the North Sea. Any ship encountering such a steep wave would be snapped in half, but rogue waves are very rare. The 1978 sinking of the MS München, attributed at the time to 'severe weather', is the only confirmed case. **LV**

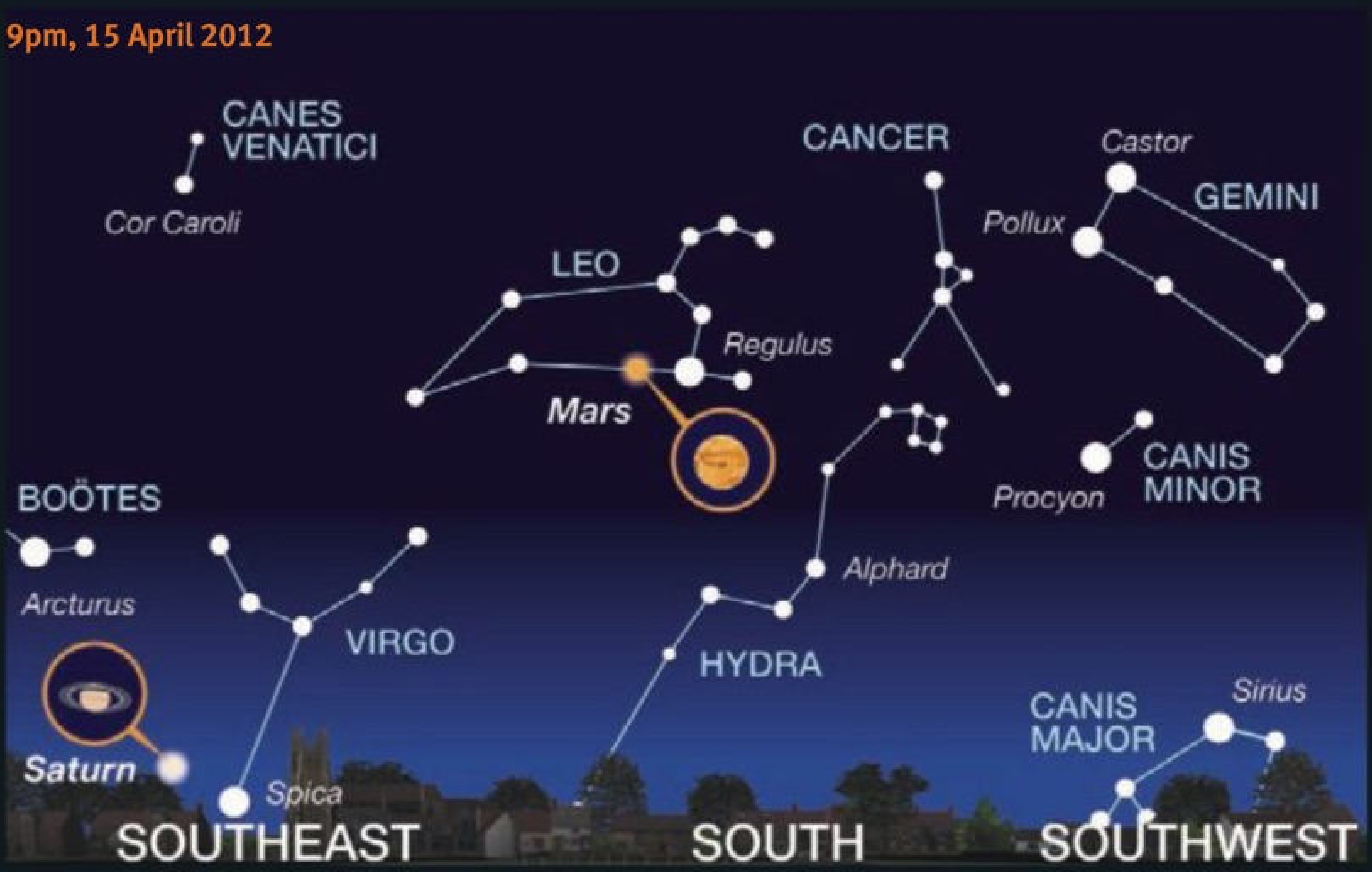
What would happen if you dropped a bomb into a volcano?

PETER WARREN, EMAIL

When Mount St Helens erupted in 1980, the initial blast was equivalent to around seven megatons of TNT. That's broadly equivalent to the yield of modern thermonuclear weapons. But the explosion that blows the top off a volcano is only a small part of the total energy released during the eruption. If you dropped a nuclear bomb into the crater of an extinct volcano, you would flatten the mountain out a bit but you wouldn't set the volcano off because there wouldn't be any pre-existing upwelling of magma. On an already active volcano, or one that is just about to blow, a nuclear bomb might alter the lava flow, or cause it to erupt a little sooner.

The US Army and Air Force have conducted trials with conventional bombs in Hawaii, to try and block or divert the course of individual lava flows, on numerous occasions since 1935. The results have been mixed at best. Lava is heavy, hot and very determined. **LV**

Skywatching with astronomy gurus Heather Couper and Nigel Henbest



9pm, 15 April 2012

What can I see in April?

- **2 and 3 April, west, 9pm–midnight**
Venus, the goddess of love, gets up close and personal to the maidens of the Pleiades star cluster. It's a great photo opportunity, and a must for binoculars or a small telescope. Keep an eye on our neighbour-world for the rest of the month as well, as she changes into a crescent on her approach to Earth.

- **15 April, south, all night**
Ringworld Saturn is at opposition tonight – opposite the Sun, and closest to the Earth. It's an intruder in the constellation of Virgo, appearing a little bit brighter than the constellation's chief star Spica. Saturn is an incredible world to view through a telescope.

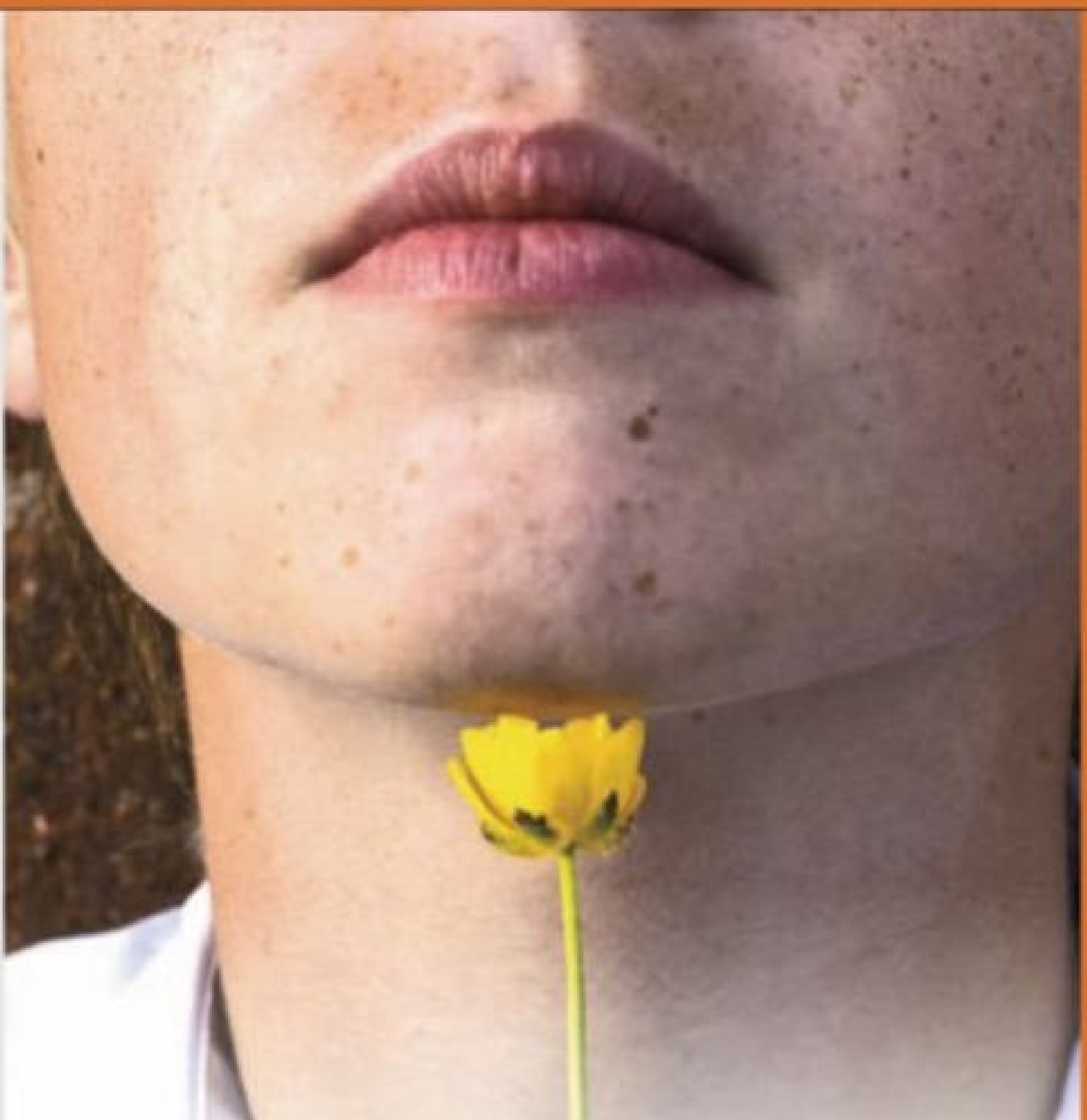
- **21-22 April, northeast, after midnight**
A celestial fireworks display – it's the maximum of the Lyrids meteor shower. These fragments from Comet Thatcher pour into our atmosphere at a rate of roughly 10 shooting stars an hour.

Why is water so essential to supporting life?

DAVID GREANEY, LEEDS

We don't know for certain that it is. There may be life on other planets based around the chemistry of liquid methane, or even creatures inside stars, powered by fusion. But on Earth, water definitely *is* a prerequisite. Water is a polar molecule, with positively charged hydrogen atoms and a negative oxygen atom. This makes it a good solvent of other polar compounds. It also creates hydrophobic interactions that make oily compounds form into bubbles, which helps materials self-assemble into cells. The electrostatic bonds formed by water molecules help to stabilise the shape of large proteins, but aren't so strong that they prevent chemical reactions.

Water is common over the surface of Earth and has the unusual properties of remaining liquid over a large temperature range, and floating when it freezes. Both of these properties help to keep our oceans from freezing over. **LV**



Why do buttercups reflect yellow on your chin?

SIMON POPE, LEICESTER

Buttercups are yellow because of the carotenoid pigments in the petals – but simply being yellow isn't enough. The yellow glow that they cast onto your chin or anything else nearby is seen because they are exceptionally glossy. Recent research at the University of Cambridge has found that this is due to a very flat layer of epidermal cells that are separated from the rest of the petal structure by a thin air gap. Light reflects both off the top surface of the epidermal cells and the epidermis/air interface on the underside. This gives a reflectivity comparable to glass. The epidermis also reflects strongly in the ultraviolet range of the spectrum. This helps attract pollinating insects (which can see in the ultraviolet) to what is otherwise a rather insignificant, low-growing meadow flower. **LV**

QUICKFIRE

What is at the centre of the Milky Way?

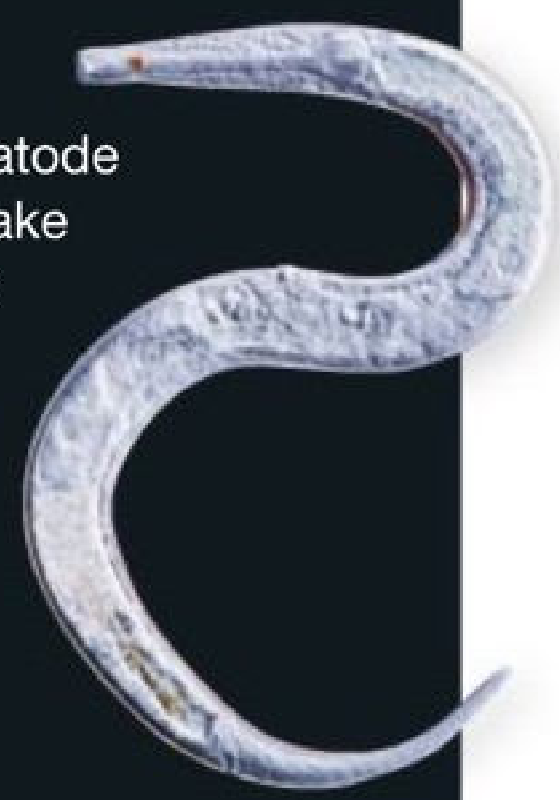
CLAIRE BROOKING, ROMFORD

At the centre of our Galaxy, which lies about 26,000 light-years away in the constellation of Sagittarius, is a supermassive black hole. By observing stars in orbit around this black hole, astronomers estimate that it is about 4.3 million times the mass of the Sun and about as large as the orbit of Uranus. **AG**

Do all animals have a brain?

PAUL BRUNDRETT, EMAIL

No. Many very small animals have nervous systems that are hard-wired into a series of reflex behaviours. Nematode worms, for example, make do with a ring of nerves around the mouth that is more like a 1950s telephone exchange than a brain. Sponges are also animals, and they have no nervous system at all. **LV**



What if the Higgs boson doesn't exist?

MAX BAILEY, LONDON

The Higgs boson is widely believed by theorists to be the neatest way of explaining why particles have mass – hence the excitement over possible sightings of the Higgs at the LHC. But there are alternative explanations. These include the idea that the role of the Higgs is performed by other particles, or even by hidden dimensions of the cosmos in addition to the three spatial dimensions we observe. No wonder some theorists would prefer the Higgs not to be found. **RM**

DID YOU KNOW?

Inhabitants of affluent Monaco (GDP per capita: $151,000) have an average life expectancy of 89.78 years. In Angola (GDP per capita: $5,911), average life expectancy is just 38.76 years.

1,900

Average number of microscopic fibres released by a synthetic garment each time you wash it. Such fibres are now a major cause of oceanic pollution

NEXT MONTH

What is the noisiest animal in the world?

How much energy does a wind turbine produce?

Does environment affect the taste of alcohol?

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The **Guide**

Everything for the clued-up consumer

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Internet TV: can the UK's infrastructure cope? 109

NATIONAL SCIENCE AND ENGINEERING WEEK

With over 4,000 science events springing up throughout the country this month, **Helen Pilcher** picks some highlights

Ever wondered if a cheetah could outsprint Usain Bolt, or if a car can travel faster than a bullet? Will invisibility cloaks ever see the light of day, and are teddy bears evolving? Now's your chance to find out, as the events of National Science and Engineering Week kick off in a town near you.

Taking centre stage will be Birmingham's Big Bang Fair. Bustling, noisy, and packed to the rafters with young people, the sheer variety and scale of events can be overwhelming but don't be daunted. Have your programme primed, your elbows ready and get stuck in to theatre shows, workshops and interactive activities. You can build a chocolate bridge, design a Mars robot and find out how to save the planet in 60 minutes, while the companies and organisations manning the glut of stalls on the show floor provide youngsters with two exciting opportunities. First, the chance to fill carrier bags with free, logo-laden stuff – think pens, sticky notes and goggle-eyed pom-poms. And second, and more crucially, the chance to interact with friendly researchers offering scientific know-how, careers advice and bucketloads of enthusiasm.

But while the Big Bang Fair boasts big names and big shows, there are many lesser-known but equally bright luminaries to be found at the thousands of events taking place up and down the country. Bangor Science Festival, for example, plays host to the enigmatic Professor Martin Raff. Best known for his work on cell suicide, Raff re-entered research after his grandson was diagnosed with autism, and will be discussing his unorthodox views on the condition.

Leeds, London, Bristol and Dundee can look forward to funny man Marc Abrahams compering the Ig Nobel Awards Tour show. The spoof Nobels reward improbable research – the wasabi fire alarm, the bra that doubles as a gas mask, a rollercoaster therapy for asthma – and the evenings will feature songs, silly science and guest appearances from Ig Nobel laureates. And if that's not enough to put your electrons in a spin, then head down to Cornwall and meet the team that, next year, hopes to smash the world land speed record in a jet car called the Bloodhound SSC.

The events of National Science and Engineering Week are as diverse as a tropical rainforest and packed as densely as a neutron star. Well, almost. But from Big Bang to Bloodhound, cheetahs to chocolate, every event has the same admirable goal. To inspire our next generation of scientists… and to have some fun!

Dr Helen Pilcher is a freelance science journalist

National Science and Engineering Week, 9–18 March
For full details of these events and many more, visit www.britishscienceassociation.org

CORBIS/BLOODHOUND SSC

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The **Review** Squad

Gwynne Dixon
A former deputy editor at Totalvideogames.com, we called on Gwynne's gaming knowledge this month and got him to test-drive Sony's new PS Vita.

Jo Tinsley
Jo's an outdoor girl at heart, and spends her days as features editor of *Countryfile* magazine. We asked her to put the latest waterproof coats to the test.

Prof Lewis Wolpert
As a biologist and the author of *You're Looking Well*, Professor Wolpert was the ideal person to give us an honest appraisal of David Bainbridge's *Middle Age*.

Jheni Osman
Former *Focus* editor Jheni is an author and science journalist. She always has her finger on the pulse when it comes to compiling our events guide.

Timandra Harkness
Every month, Timandra scours the schedules of dozens of TV channels and radio stations to bring you the month's very best science programmes.

Dell recommends Windows® 7.

DELL

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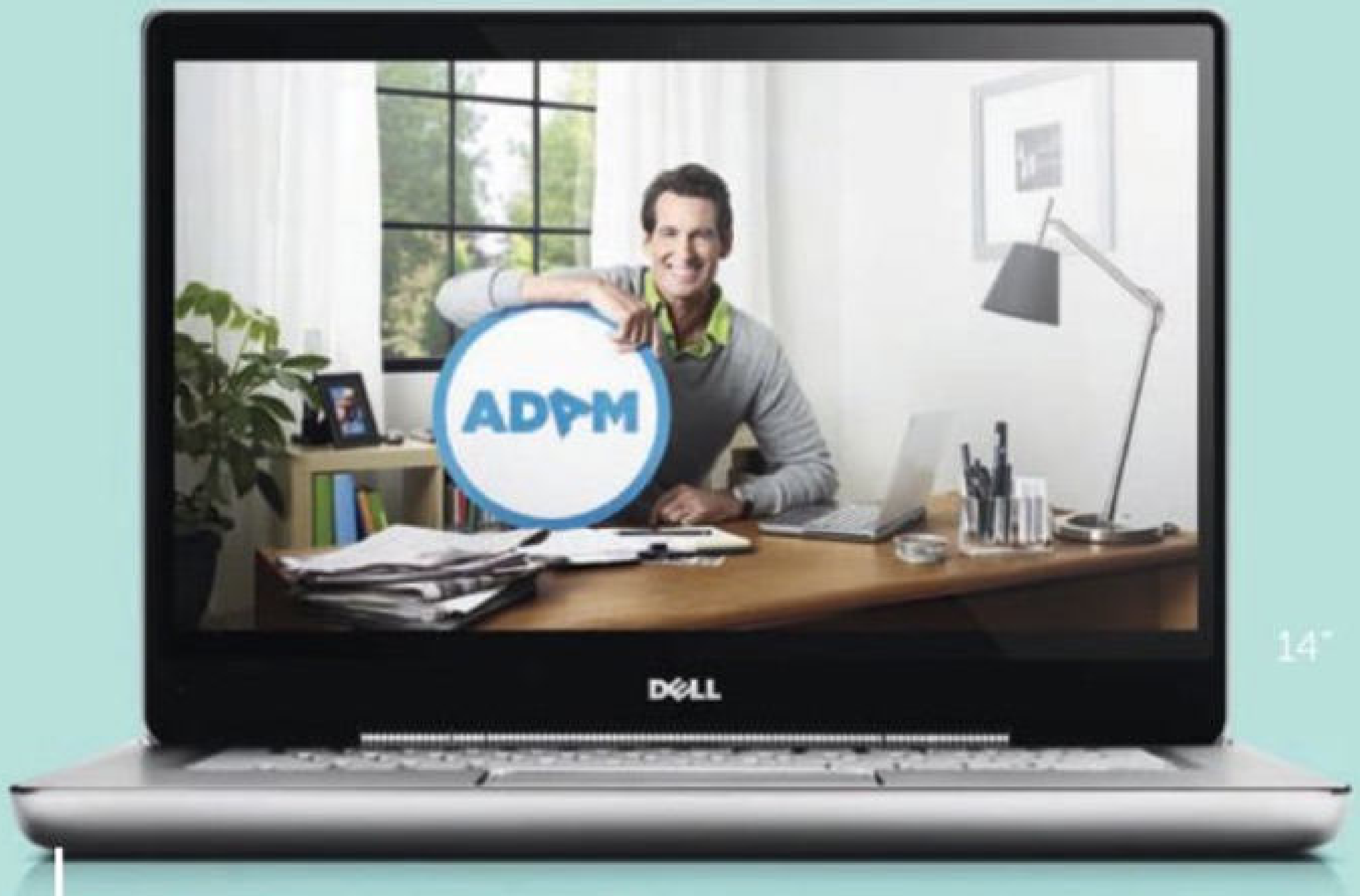

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intel inside™
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THE SHAPE OF SCREENS TO COME

Meet the ultra-slim TV of the (very near) future

How would you like a 55-inch TV that's as thin as this issue of *Focus*? That's 4mm thick, in case you were wondering. It might sound preposterous, but we saw LG's new flatscreen from the side at Las Vegas's big electronics show CES recently, and it virtually disappears.

Unlike LED and LCD TVs, this set uses an OLED system that doesn't need a backlight to produce colour. Instead it relies on carbon-based diodes that light up independently when a current is passed through them. This crash diet hasn't just been healthy for the telly's figure, the picture quality is incredible too. The contrast between light and dark areas is far more pronounced than anything its predecessors could manage and the colours are so vibrant you'll find the real world starts to look a bit dull.

Unfortunately, this slender TV won't be coaxing the money out of your wallet for a while, as it doesn't go on sale until the second half of the year. And if you are tempted, we suggest you start saving now – it's unlikely to be cheap. OLEDs, however, are likely to take over the TV market, so you might be better off waiting a little while longer before splashing out.

LG 55-inch OLED TV
Price: TBC
Info: www.lg.com

BBC

Clock watching

This smartwatch conjures up the same kind of excitement inspired by the original Casio calculator wristwatch. But while no-one in history ever actually needed a wrist-mounted calc with buttons only toothpick-sized fingers could operate, the I'm Watch is actually a useful prospect. By tethering to your smartphone's web connection, it can make calls, access your address book, receive Facebook and Twitter updates and much more. It's Android-based so there'll be plenty more apps to come in the future, too.

I'm Watch
Price: €249 (£206.78 plus P&P)
Info: www.imshop.it

Boxing clever

Although its name isn't so clever – strictly speaking, the Logitech Cube is actually a cuboid – this is a smart mouse. When it's lifted off a work surface it switches to presenter mode to control Powerpoint slides. A click on the top moves the presentation forward, while pressing the underside will send it back. Back on the desk, the mouse has a touch-sensitive surface and is about the size of a matchbox.

Logitech Cube
Price: £59.99
Info: www.logitech.com

Greased lightning

This road bike is so quick it should be illegal. Actually, in racing terms it is. The Cervélo P5 TRI comes to a stop using hydraulic brakes, which are banned by the UCI (Union Cycliste Internationale), so you won't see this in the Olympics or the Tour de France. The brake levers compress oil inside the brake wires, which in turn force the brake callipers to clamp down on the wheel. This may seem like an elaborate way to stop a pushbike, but it shaves crucial grammes off the bike's total weight and offers a smoother halt.

Cervélo P5 TRI
Price: £4,499
Info: www.cervelo.com/p5

High fidelity

This is, without a doubt, the most high-tech pair of headphones we've ever come across. It includes NFC technology for one-touch wireless pairing, a touch-panel in the right can for volume and track controls, and a sensor system that pauses your media player when you take your headphones off. But its most intriguing trick is that it channels audio to sound like the music is coming from in front of you, rather than being aimed directly into each ear. Having tried out a prototype pair, we can vouch for the effect: it's as close as you'll get to having a live band playing in front of you, without leaving your sofa. Oh, and it's sculpted by French design guru Philippe Starck as well.

Parrot ZIK by Starck
Price: TBC
Info: www.parrot.com

What are you looking at?

Imagine switching between multiple windows on a computer simply by looking at them. The black bar below this laptop's screen enables you to do exactly that. It's an infrared projector and receiver that tracks where your gaze is focused and places the cursor on that exact spot. Then when you place a finger on the touchpad, it turns off the eye-tracking, letting you adjust the controls by hand. We tested the laptop with two Word documents, and it seamlessly and accurately shifted the mouse between them with ease.

Tobii Laptop with Eye Tracking
Price: TBC
Info: www.tobii.com

Old dog, new tricks

The best sound systems don't tend to come Airplay-enabled or with an iPod dock built-in. The solution? Plug this device into a set of standard speakers via an optical audio cable, and it'll let you wirelessly stream music over your home network to your existing hi-fi, from an iPhone or a Mac with Airport Express.

Griffin Twenty
Price: TBC
Info: www.griffintechnology.com/twenty

PS VITA

Can Sony's new high-spec handheld live up to all the pre-launch hype? **Gwynne Dixon** spends a week with one to find out...

What is it?

Sony's new handheld games console is the successor to the PlayStation Portable (PSP). Arriving seven years after the original, this second bite of the cherry is without a doubt the most powerful gaming device ever to fit into a pocket.

What does it do?

The PlayStation Vita's graphics are, without a doubt, the best you'll find outside of a full-fat console – no other portable can even hold a candle to the sort of visual displays of which it's capable. The Vita is effectively 70 per cent of the way towards a PlayStation 3 in terms of power and visual fidelity.

It's also souped-up in more ways than a hot rod. There are front and rear cameras, dual thumbpads, a rear touch-panel, five-inch OLED touchscreen, Sixaxis tilt controls... basically, it's every game control method under the Sun, crammed into a device around the size of a glasses case. It is, at the very least, incredibly ambitious.

What's the catch?

It's all a bit *too* ambitious. The Vita lands halfway between its predecessor – a handheld aimed squarely at the hardcore gamer – and the new casual gaming experience offered by smartphones and tablets. By dividing its attention between the two, it pleases neither. Casual gamers will be put off by games that demand longer sessions, and the fact that it doesn't fit in your pocket particularly snugly, while this hardcore gamer, at least, found the hotchpotch of traditional and touch/motion controls unappealing.

How does it compare to other handheld devices?

Unfavourably, mostly. The web browser doesn't support HTML5 or Adobe Flash, which renders online media such as embedded videos redundant, and while the Vita can download music and video from your PS3 or PC easily enough, it's quite fussy about the file types it's willing to play. Touch and tilt controls are on a par with a smartphone or tablet, but Sony is yet to find an alternative to the kind of impulse-buy, £1 games you can find on Android and iTunes.

In comparison to Nintendo's 3DS, the Vita feels and plays like a much more grown-up device. The ergonomics are better and the games are clearly aimed at a more mature audience. There's also the option to buy a more expensive model that offers 3G internet, though this top-tier Vita will be twice the price of a 3DS at launch and lacks the casual appeal of Nintendo's handheld.

Should I buy one?

Probably not – at least, not yet. It really is a lovely piece of hardware to behold, but it'll live or die on the strength of its software. The Vita has an impressive launch line-up of over 30 games, and yet more big titles confirmed for release further down the line (eg *Call Of Duty*, *BioShock* and *Assassin's Creed*). As long as this kind of support continues, the PS Vita could be worth the £230+ investment. For now though, unless you're a dedicated Sony fan or a serious gamer, it might be worth holding on to your cash.

LAUNCH GAMES

Uncharted Golden Abyss

Probably the best graphics in the launch line-up and a superb handheld translation of *Uncharted*, but the touch and motion controls can dilute the experience somewhat.

Wipeout 2048

Great racing action in the true *Wipeout* tradition, but that's about it – and you're best off sticking to the conventional gamepad controls once you get past the menu screens.

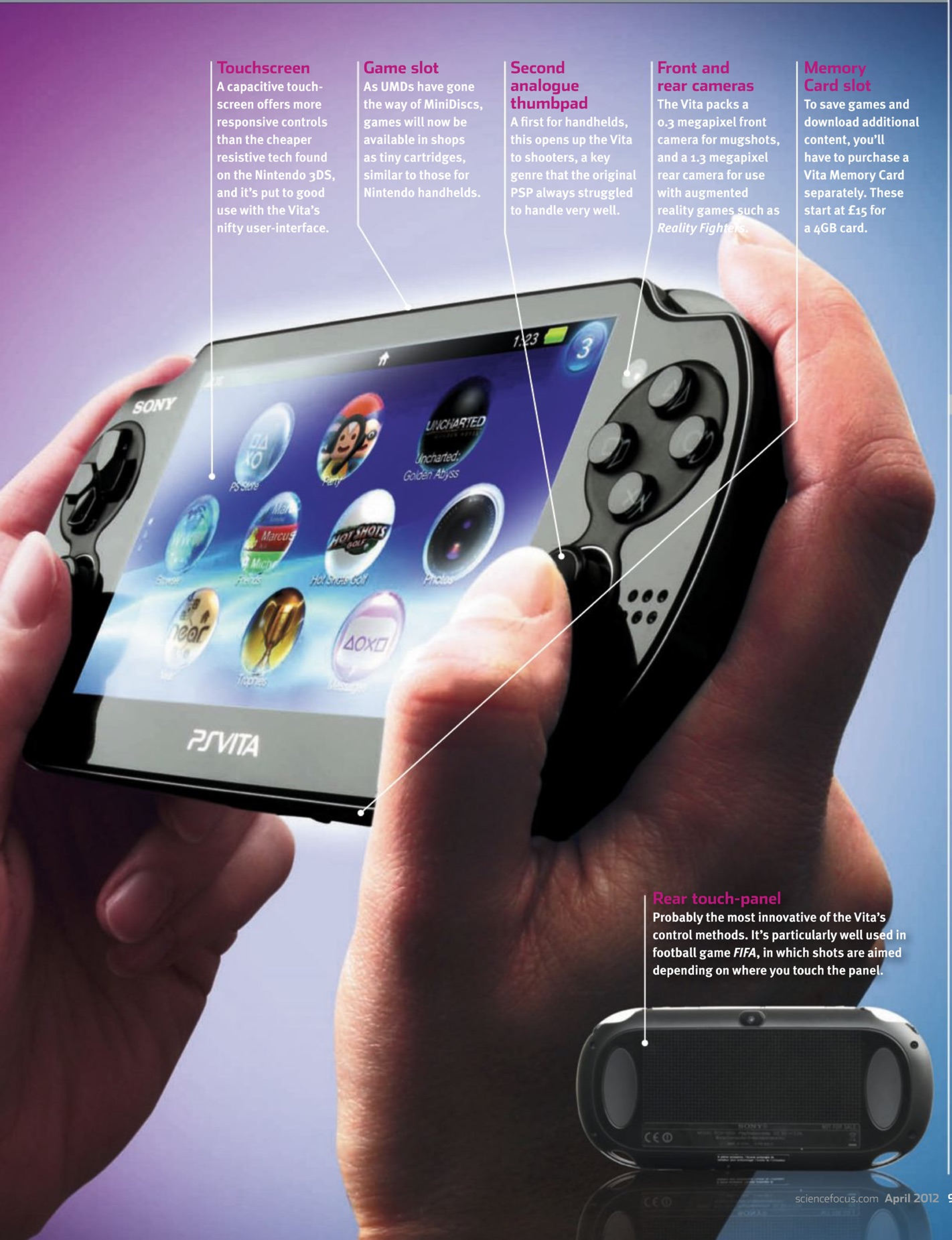
FIFA Football

With tons of teams and features, the handheld version of this football series has been brilliantly translated, with added touch controls to boot. A must for footy fans.

Reality Fighters

An augmented reality fighting game that uses the Vita's front camera to give your character your face, and the rear camera to superimpose him or her on a nearby surface.

WWW.STUDIO4PHOTO.CO.UK



Touchscreen
A capacitive touchscreen offers more responsive controls than the cheaper resistive tech found on the Nintendo 3DS, and it's put to good use with the Vita's nifty user-interface.

Game slot
As UMDs have gone the way of MiniDiscs, games will now be available in shops as tiny cartridges, similar to those for Nintendo handhelds.

Second analogue thumbpad
A first for handhelds, this opens up the Vita to shooters, a key genre that the original PSP always struggled to handle very well.

Front and rear cameras
The Vita packs a 0.3 megapixel front camera for mugshots, and a 1.3 megapixel rear camera for use with augmented reality games such as *Reality Fighters*.

Memory Card slot
To save games and download additional content, you'll have to purchase a Vita Memory Card separately. These start at £15 for a 4GB card.

Rear touch-panel
Probably the most innovative of the Vita's control methods. It's particularly well used in football game *FIFA*, in which shots are aimed depending on where you touch the panel.

Singing in the rain

As April showers loom on the horizon, **Jo Tinsley** puts this (rainy) season's waterproof jackets through their paces

British adventurer Sir Ranulph Fiennes once said: "There is no such thing as bad weather, only inappropriate clothing." In a country with an average 154 rainy days a year, that's a lot of shoddy coats. But unless you find an outdoor clothing store with a power shower in the changing rooms, it's hard to tell if a jacket will hold up to a downpour. Which is why, on the coldest day of 2012, I found myself in a photo studio on the outskirts of Bristol, clad head to toe in wet weather gear.

I wanted to put four of the latest waterproofs through a series of experiments, to see how they stood up to various weather conditions. I wore a grey t-shirt underneath and, after each test, noted how much water got through. Each jacket represented a different approach to waterproofing, from supposedly impenetrable membranes to fabrics that open and close like fir cones in response to the weather. But could they handle a severe *Focus* drenching?

How we tested the coats

The Northern Mist Test

Using a hose set to a fine spray, we faithfully reproduced drizzle in studio conditions. We designed this test to simulate the bane of my young life growing up near Manchester. Glaswegians call it smirr, Cumbrians mizzle, but we all know it as 'that fine rain that soaks you through'.

The Heavy Rain Test

Here we replicated a proper torrential downpour, the kind you get in a summer storm, using a watering can, a long arm and a step ladder. Our aim was to test the waterproofing of the fabric to the limit, as well as assessing the hood and sleeve cuffs.

The Hose Test

This test aimed to find the weak points of each jacket, using a garden hose to target zips, seams and pockets. Although this simulates far more extreme conditions than your jacket will have to endure, we wanted to expose potential design flaws.

The Lorry Test

We wanted to simulate the curse of the humble pedestrian – a thorough soaking caused by a deep puddle and a passing lorry, recreated by a direct hit from a bucket of water. This tested both the fit of the hood, and your dutiful tester's composure.

PHOTOGRAPHY: ADAM GASSON

Kathmandu Breccia

£189.99

The Breccia mimics the way a fir cone opens and closes in response to rain. Its “revolutionary intelligent membrane”, called c_change™, opens up to let water vapour escape during warm weather or aerobic activity; then, when it’s cold outside, the membrane reverts to its original structure in order to retain your body heat.

With the thermometer hovering around zero we couldn’t test the warm weather theory, but the Kathmandu jacket was impervious to our Northern Mist. It slipped up slightly on the Heavy Rain test, as water dribbled down the sleeves despite the adjustable cuffs. But it did stand up to a drenching from a full bucket of water with not a drop sneaking in around the hood, which has a useful wired peak and is adjustable. It also coped surprisingly well under the hose, despite having no extra layer to protect the zips. The water also beaded so well on the surface of the jacket that after a couple of shakes, it was dry enough to go back in my bag.

Fit: ●●●○○
Features: ●●●●○
Breathability: ●●●●○
Test performance: ●●●●●
Overall: 16/20

Páramo Vista Jacket

FOCUS BEST BUY

£210

Páramo’s jacket was the softest, most lightweight and rustle-free of the four. Because it doesn’t rely on a waterproof membrane, I’d been warned that water could be forced through the fabric under pressure. Armed with his hose, Reviews Editor Dan gleefully tested this, but after a good soaking only a tiny amount of water had seeped in – perhaps thanks to the poppered flap under the zip. It fared well under both drizzle and torrential rain, and felt remarkably warm, though the Lorry Test proved trying as it had a slightly floppy hood, so water trickled down my neck. It also had curiously high chest pockets, presumably designed for a T. rex.

The Vista’s forte is its breathability. Its Nikwax Analogy fabric claims to wick perspiration away from the skin more effectively by mimicking mammal fur. So efficient is it, in fact, that Páramo suggests you could stick pins through the fabric of the coat and it would still keep you dry – though we didn’t try this in our tests.

Fit: ●●●●●
Features: ●●●●○
Breathability: ●●●●○
Test performance: ●●●●●
Overall: 18/20

Berghaus Chogori II

(Men's version called Temperance)

£240

Fit: ●●●○○
Features: ●●●○○
Breathability: ●●●●○
Test performance: ●●●●○
Overall: 14/20

This is a thicker, crunchier waterproof than the rest. It's also longer on the body, and is tapered low around the back with a deep hood and lengthy sleeves. Cuffs proved problematic across the board, but the Chogori's loose fit meant more irksome drips snuck down the sleeves and there was some neck wetness after our Lorry Test. But the taped seams and zips took a thorough hosing without any seepage, so it is a reasonably waterproof option.

Keeping the rain at bay is only half the battle, though. Breathability – the way a material moves hot water vapour through to the outside of the jacket where it can evaporate – is equally important. Stride up a mountain in a bin bag and you'll see why! Berghaus uses Gore-Tex, a membrane with around nine billion pores per inch, each 1/20,000th the size of a typical raindrop, so it's impenetrable to water. However, while this is one of the most waterproof and durable fabrics available, in terms of breathability it's not as airy as its rivals.

Finisterre Anabatic II

£160/£180 (Women's/Men's)

The Anabatic II felt rather flimsy compared with the other coats – it's lightweight and packable, but I'd also worry about ripping it, and it felt colder. That said, it stood up perfectly to the Northern Mist and Heavy Rain tests. Alas, the Anabatic II gave up the ghost when we put the hose on it, leaving a thin wet line down my front where the water had breached the zip. A direct hit from the bucket further drenched my neck.

Finisterre's own membrane technology moves moisture away from the body while remaining water- and windproof. Like all the jackets, the Anabatic II showed impressive beading – droplets of water ran straight off the fabric and, after a quick shake, it was bone dry. Although probably the least waterproof jacket here, the Anabatic excels in sustainability. It's designed and made in the UK from part recycled and 100 per cent recyclable material. It's also got some nice design features – OS map-sized pockets, a good hood with a wired peak, and a nice long fit around the arms and in the torso.

Fit: ●●●○○
Features: ●●●●○
Breathability: ●●●●○
Test performance: ●●○○○
Overall: 13/20

Verdict

All four jackets stood up well to our home-baked experiments – they breezed through the Northern Mist test and, apart from a few wet elbows (my fault for adjusting my hood mid-downpour) our Heavy Rain, too. All of the jackets beaded well and were dry enough to put away minutes after the test. The Lorry and Hose tests showed up a few potential faults, but in reality it's unlikely your jacket will have to stand up to this sort of abuse.

Finisterre's Anabatic II looks dapper and would keep you dry in a downpour, but tripped up during the hose test due to unprotected zips, and was rather flimsy for my liking. But as the cheapest jacket on test, it's still worth considering, especially as it packs down to the size of a baked potato. The Berghaus is reliable, hardy and would keep you dry in a hurricane, but it had a crunchy, vaguely clammy feeling against wet skin and, as waterproof as it is, I can't help but have concerns about its breathability.

The Kathmandu strode ahead in terms of innovation, with temperature-sensitive technology that focuses on allowing moisture to escape as much as it does on creating a barrier against rain. If you're going to be working up a sweat in the outdoors, this coat will keep you dry and comfortable, while looking stylish to boot.

Just in the lead, however, is Páramo's Vista. If you can forgive the T. rex pockets, this unique jacket offers something rather special. It will keep you dry inside and out, whether it's bitter, balmy or tipping it down. So that's the British summer sorted, then.

FOCUS
BEST BUY

Gear up for a soggy summer!

Alpinestars Slipstream

With all their zips and stitching, it's hard to find a fully waterproof backpack. But the Alpinestars Slipstream – suitable for mountain bikers, motorcyclists and wet-weather commuters – is completely stitch-free to keep water out, while a padded sleeve keeps your laptop snug.
£124.99, www.alpinestars.com

Nikwax TX Direct Spray-On

Most waterproofs are treated with durable water repellent (DWR), which does eventually wear off. But help is at hand! Nikwax's TX Direct Spray-On coats your clothing with a network of elastic TX.10i molecules, which bond to and protect anything that's not already water-repellent.
£10, www.nikwax.com

Motorola Defy + JCB

This extra hard-wearing smartphone has been specially beefed up by JCB for use on building sites. It's waterproof too, so whether you just need to get your phone out in a downpour or happen to drop it down the side of a mountain, the Motorola should be able to cope.
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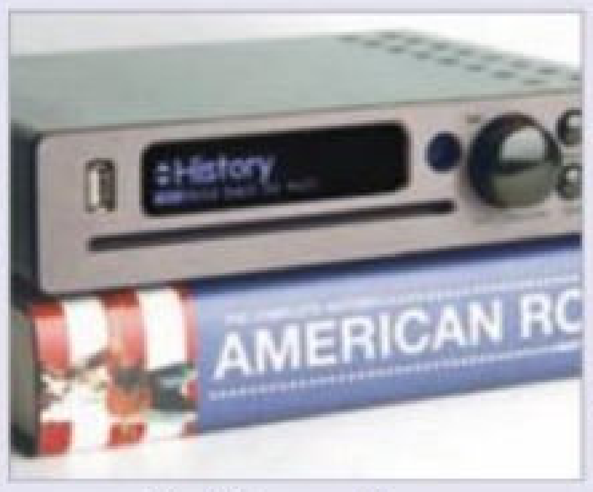

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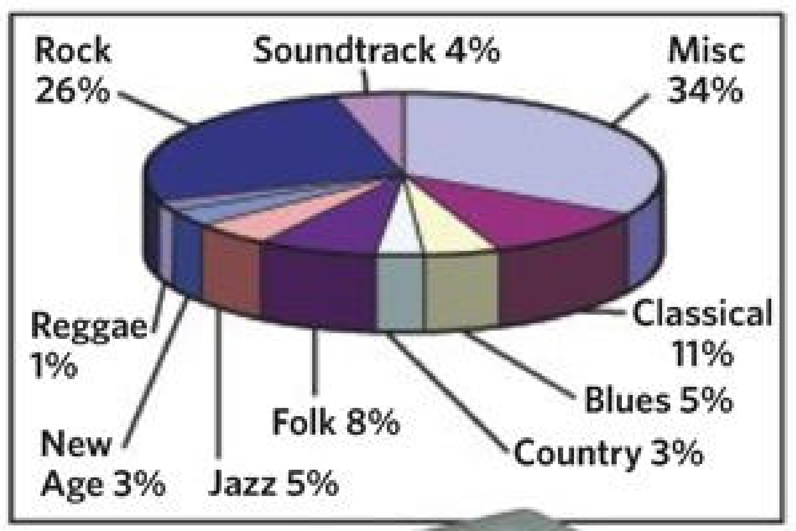

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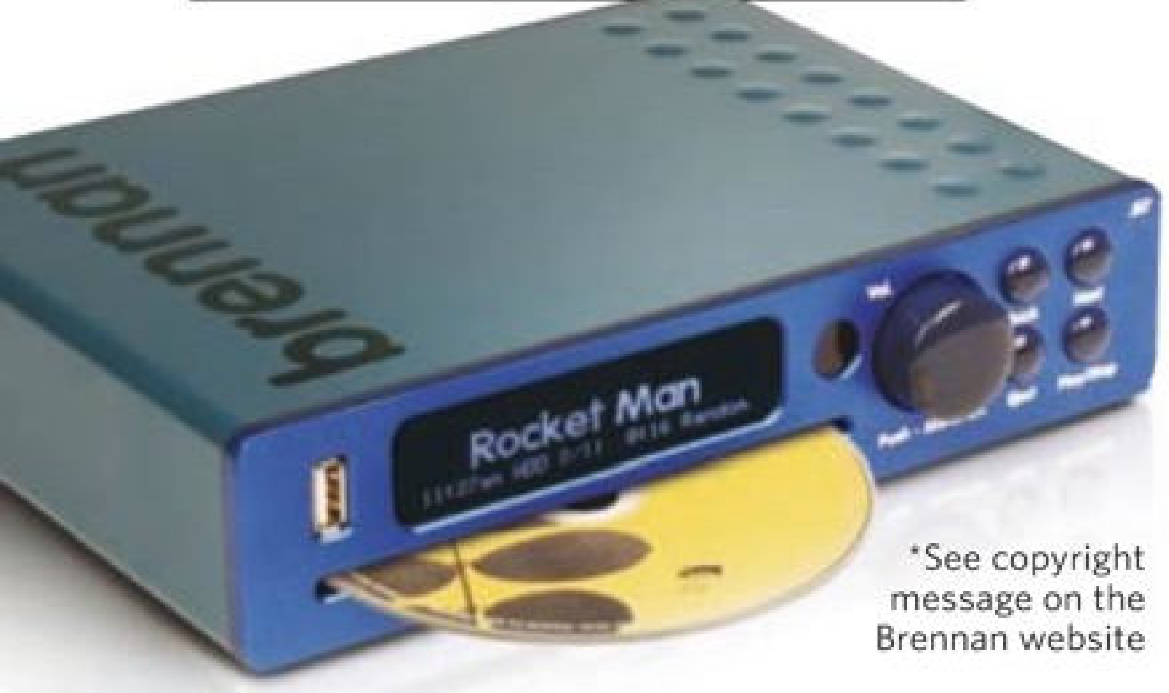

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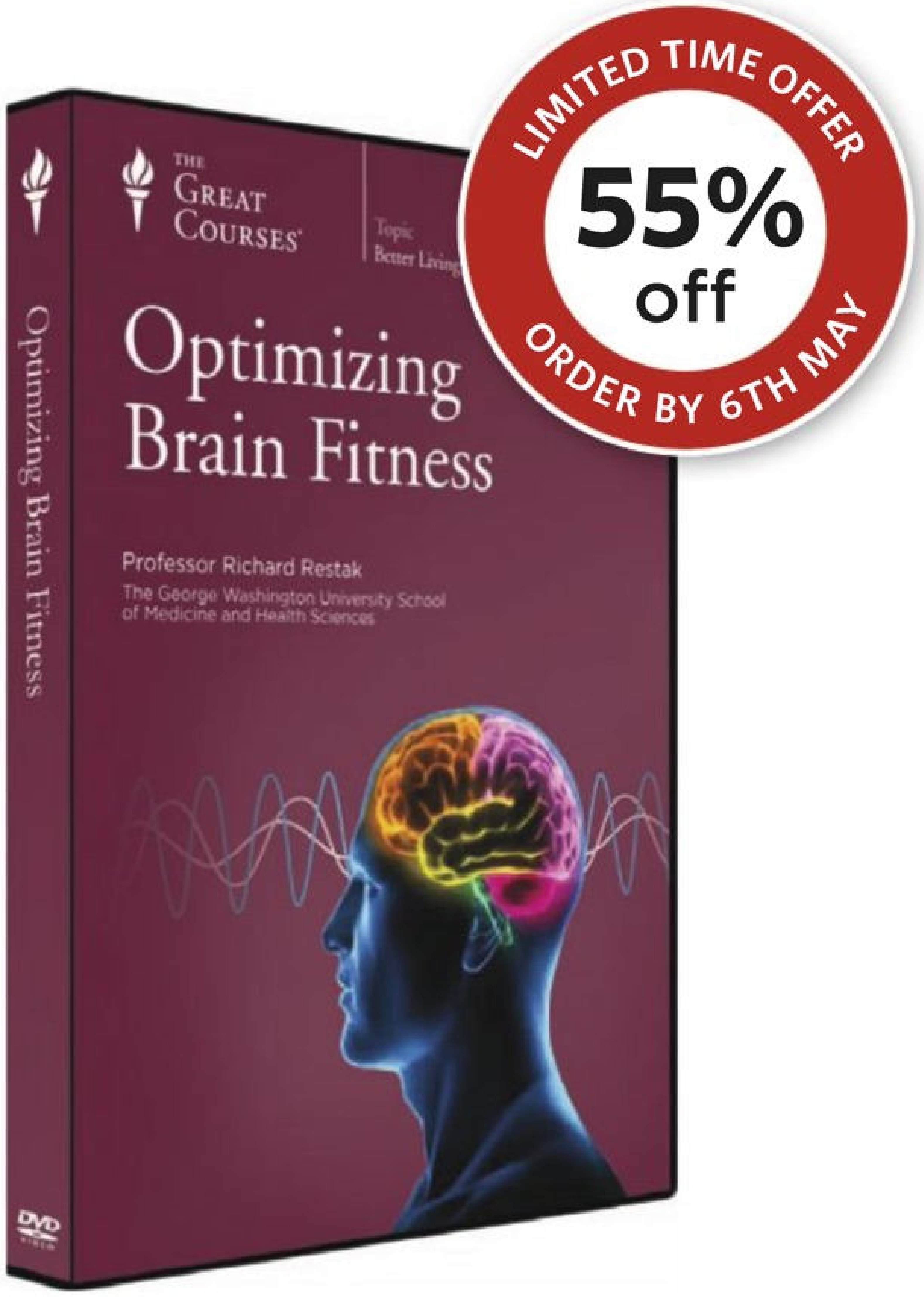

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Spencer Kelly

Cool connections

Nothing says 'the future' quite like web-enabled kitchen gadgets. After all, haven't you always wanted to be able to tweet about your low-fat spread of choice as you bask in the fridge's chilly glow?

Well, maybe not. But for years, futurologists with little imagination have combined existing technologies to predict disco-lit dishwashers and intuitive cupboards. Many of these innovations, though, rely on manufactured necessity. They solve a problem that we never really had, while adding another time-consuming step to your busy day.

Take the net-connected fridges released by the likes of Samsung and LG this year. They'll let you know when you're running low on milk, for example – as long as you've told them everything you've bought first, via a touchscreen.

Fortunately, we're starting to see some more sensible thinking based around an idea called the 'internet of things', whereby appliances as well as computers are going online. And thanks to the ubiquity of home Wi-Fi networks, tablets and smartphones, they don't all need their own expensive control screens. Instead, this year will see the arrival of washing machines and ovens that, should you be running late, can be remote-controlled from a phone app. Central heating systems that let you warm up the house via your smartphone before you get home are already available.

This is the kind of connected tech that I do want to live with. I don't need my fridge and washing machine to play YouTube videos, thanks. But I would like them to be just smart enough to talk to a central home monitoring system that keeps everything in check – and keeps me in fresh milk and clean clothes.

No browser required

Spencer Kelly is the presenter of the BBC's technology show *Click*

How to...

GET MORE FROM YOUR MUSIC PLAYER

Being able to take your tunes with you everywhere you go is brilliant, but are you getting the best possible sound from your portable? Here are some tips to make sure you are...

HEADPHONES

Replace the freebie pair supplied with something more substantial. Headphones that enclose your ears typically provide better sound and tend to be more comfortable to wear. However, if you do need light, convenient ear-buds, then you could try a home custom-moulding kit such as Sonomax's eers PCS range. This fills your ears with quick-setting silicone to create a pair of buds that will perfectly fit your lugholes.

BIT RATES

When you buy or rip music, you can often choose the bit rate. The higher the better: don't go below 128kbps, and aim for 320kbps. The type of file also matters: for any given bit rate .OGG and .AAC are generally better than MP3, if your device can play them. For the best results, you could opt for a lossless format like FLAC, which gives CD-quality sound, though you'll need plenty of hard drive space and a player that's compatible.

AMP IT UP

Real audiophiles use a headphone amp. Its job is not necessarily to make things louder, but to make your headphones sound more expensive than they are. It'll be most useful if you're using big headphones that require more power than your puny MP3 player can deliver, and least useful when using noise-cancelling headphones, which already have a built-in amp. If you're on a budget, the FiiO E6 is a wallet-friendly option.

Tech Doc's app prescription

SOLAR WALK

iOS

This free app lets you pinch, zoom and swipe your way between planets and moons. The images are gorgeous, the animation smooth and the extra info about each object illuminating. If you own a 3DTV or a pair of red and blue 3D glasses, you can even watch the planets hover in front of your screen.

ENDOMONDO

Android/iOS/BlackBerry/Windows Phone

This is a free fitness app with its own social network. Choose a sport, and then start running, skating, cycling or walking. Your course is tracked using GPS, and you can share your performance with others. And because you're a competitive sports nut, you can download other users' routes and try to beat their times.

We've all done battle with the odd green-eyed monster, but really...

STAR WARS: THE OLD REPUBLIC

PC

BioWare, £44.99 plus subscription

The Old Republic immerses you in a huge multiplayer rendering of that galaxy far, far away as it was a long, long time ago. Set before the events of the movies, when the Sith Empire and the Galactic Republic co-existed under an uneasy truce, you pick a side and create a character from a selection of types (such as a Bounty Hunter or Jedi Knight), then take them online to quest and fight across several planets alongside everyone else's characters.

All the staples of massively multiplayer online role-playing games (MMORPGs), such as team-based missions, are executed with flair and fidelity to the *Star Wars* universe. The iconic lightsaber thrum and blaster zap are present and correct, as are a sweeping cinematic score and cheesy cantina tunes. It looks lovely too, with awe-inspiring locations (plus some generic sci-fi corridors).

But the Death Star in *The Old Republic*'s arsenal – deployed against genre behemoth *World of Warcraft* – is its storytelling. Developers BioWare, virtuoso single-player storytellers, apply their expertise here with expressively voiced non-player characters and plotlines that branch according to your choices.

As with any MMORPG, *The Old Republic* will grow and evolve as BioWare rolls out new material and refinements. For now though, it's already a compelling slice of social multiplayer action, and makes each player feel like the hero of his or her own story. ●●●●○

Even the toilet roll dollies come heavily armed in *The Old Republic*

ALSO OUT

GRAND THEFT AUTO 3

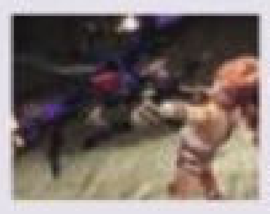
iOS, Android

Rockstar

£2.99

Groundbreaking when it arrived on consoles in 2001, *GTA 3* makes an impressive comeback in this portable edition. It's the same free-roaming, car-thieving romp through Liberty City, with the 3D graphics translating well, but the control system is the weakest point. It's been redesigned for touchscreen devices, but the controls are fiddly and fussy, and don't offer the ease and precision of the original's buttons. ●●●○○

FINAL FANTASY XIII-2



PS3, X360

Square Enix

£49.99

No game does epic spectacle like *Final Fantasy*. The story here follows on from 2009's *Final Fantasy XIII*: pink-haired Lightning returns, and you guide her and her allies through a time-travelling adventure, with group battles fought by selecting attacks from a menu. This accessible sequel is less linear and more gripping than its predecessor, while again the visuals mix gorgeous design and technical razzle-dazzle.

Jane Douglas

Playing it safe

While the movie industry is often criticised for recycling ideas, games seem even more guilty of a fondness for the familiar. Of the top 10 films at the UK box office in 2011, half were sequels; among 2011's bestselling games, eight out of 10 were direct sequels (such as *Batman: Arkham City*) or additions to established franchises (like *Battlefield 3*).

Producing an original game that's also a smash hit is tough, and successful gambits such as 2011's *LA Noire* are rare. Non-sequel blockbuster movies like *Inception* and *Avatar* are less exceptional, partly because they can bank on film stars and notable directors.

The closest games get to such superstar pulling power comes from established franchises. *Star Wars: The Old Republic* may be the most expensive game ever, with a development budget estimated at $200 million, but it's also based on one of the world's biggest entertainment brands – making the game a large bet, but a relatively safe one.

Are games publishers playing it safe with too many sequels?

With big games growing ever more expensive to make and wobbly economic times, expect major publishers to produce even fewer risky, big-budget titles. The release schedule is already awash with sequels, remakes and reboots. This year's heavy hitters will include the usual suspects (new editions of *FIFA* and *Call Of Duty*) and high-profile sequels like *Mass Effect 3* and *GTA V*.

Like the contrast between Hollywood and indie movies, great games produced on lower budgets will come from smaller studios. To find them, though, you'll have to root around mobile app stores, download marketplaces for consoles, and the PC indie scene.

Jane Douglas is section editor of GameSpot UK

Bill Thompson

Can the net cope with HD streaming?

I'm old enough to remember the internet before the web, when most online traffic consisted of text-only emails or binary files of scientific data being exchanged between researchers. Images were rarely sent, and the idea of streaming audio or video was unimaginable to all except the lucky few with access to the research-only multimedia backbone (mBone).

In 1994, I was part of a group that 'live streamed' a discussion from London's Institute of Contemporary Arts onto the early web. We built a text-only chat system and recorded five-minute chunks of the debate, then uploaded them to be downloaded and played.

Things have changed since then. Our home network connections are expected to cope with family members streaming TV from iPlayer and 4oD, gaming on Xbox Live and holding Skype conversations with relatives in New Zealand. These days the web is as much a delivery platform for streaming media as it is a hypertext publishing system, and many of us are watching HD video on internet-connected TVs and tablets.

As a result, the trend in bandwidth use is resolutely upwards – and although the network seems to be coping with the strain so far, it's unlikely that the existing infrastructure can keep up for much longer. This is why ISPs like BT are starting to use fibre-optic links to houses instead of copper wires, but doing this is costly.

Perhaps new commercial models that funnel money to ISPs could change things. In the last year we've seen Amazon buy UK-based Lovefilm, and US-based Netflix launch a UK service, while Apple continues to offer TV and films via iTunes. The amount of video streaming over the network is clearly going to carry on growing. At the moment these video services buy bandwidth like everyone else, but they could do deals with ISPs and pay more to get better access to internet-connected homes. There are dangers in simply letting these services buy their way to the top of the tree, though, and the debate about 'network neutrality' has highlighted the risks of allowing wealthy players like YouTube the freedom to do deals that give them privileged network access.

But if we want the web to deliver the widest possible range of sites and services, then we have to find a way to pay for the underlying network that makes it all work. And at the moment we don't seem to know how we're going to manage that.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

PBS Kids Science Games

http://j.mp/SciGames

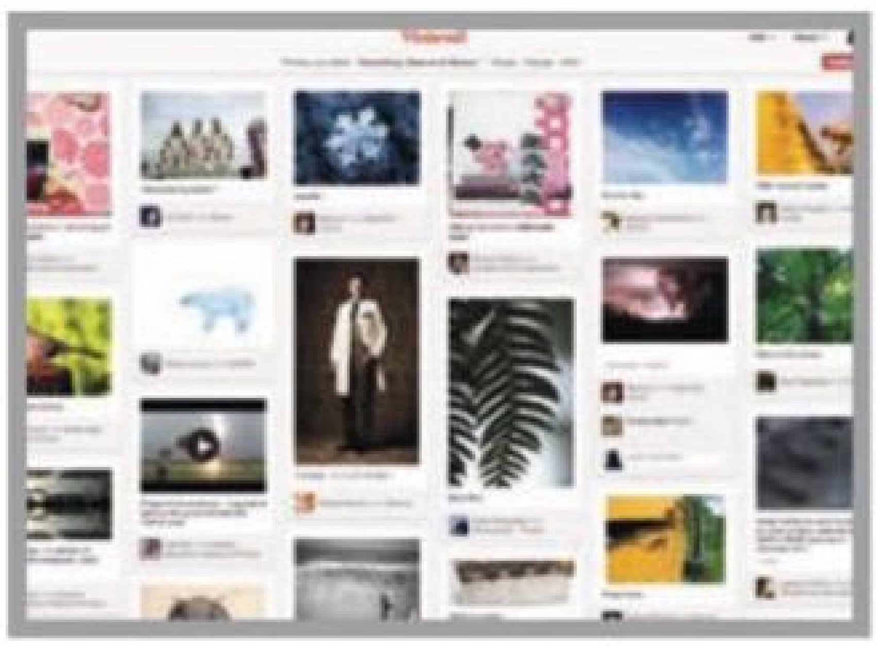
Teaching basic science concepts to young people is now a lot easier than it used to be, thanks to the many tools available on the internet. Authoring packages such as Adobe Flash have made it relatively straightforward to produce games that illustrate chemical reactions, show how gravity works, or explore ideas in biology.

However, you need some imagination and inventiveness – as well as good artists – to make those games engaging enough to ensure that the science has time to sink in. This comprehensive collection from PBS Kids shows how it can be done.

Using a range of characters from animated TV shows like *Arthur* and *Curious George*, it offers a wide selection of short games. You can choose to explore momentum with a monkey on a pogo-stick, investigate the weather, interpret animal sounds or try to move things around in zero gravity. Each game has an introduction and clear instructions, and they're great for young children – or perhaps just an adult who is tired of *Angry Birds*.

WEB HACKS

Organise and share things you find online with Pinterest



What? If, like me, you spend a lot of time online, then you're always coming across interesting images (or uploading them yourself). Pinterest enables you to keep track of all the things you find online with a 'virtual pinboard', and lets you share interesting images with friends and followers.

Why? Keeping track of all those pictures is almost impossible. I've got links on Facebook, things I've tweeted on Twitter, a whole load of stuff to read in Instapaper and (of course) an extensive selection of web pages I've bookmarked and instantly forgotten about. Pinterest lets you keep everything in one place, with as many different boards for different topics as you like.

How? Sign up for an account at www.pinterest.com. Once you're all signed up and registered, you can install a 'Pin It' button in your browser, or get the Pinterest app (iPhone-only for now). As you surf other websites, you can then add images that catch your eye to your pinboards. Other users can follow you and add comments below your images, and you get to keep all your stuff in one place.

60-Second Adventures In Thought

http://j.mp/60Thought

These one-minute animations from the Open University look at six well-known thought experiments in science and philosophy, such as Einstein's twin paradox and the 'infinite hotel' that mathematician David Hilbert conjured up to explore ideas of infinity. They're entertainingly narrated by comedian David Mitchell, and there are links through to other OU materials and courses if you want to take your study a little further.

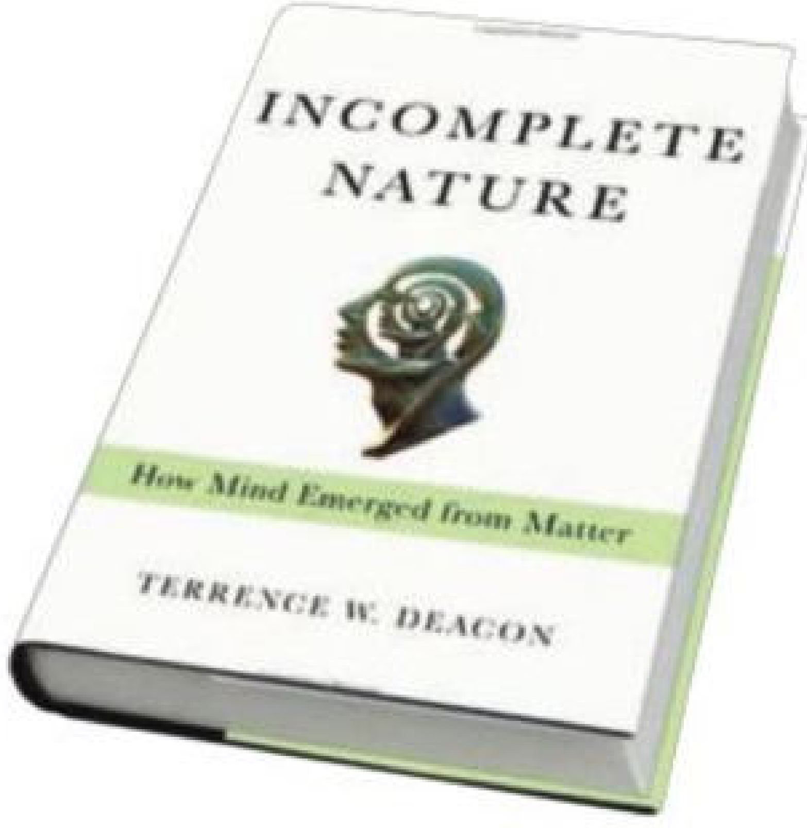
Paleofuture

http://j.mp/PaleoF

The Smithsonian's Paleofuture blog is a fascinating exploration of how people in the past imagined possible futures: everything from portable crystal radios and the 1930s view of 'the war on cancer' to weather control. It's richly illustrated and well researched, and anyone reading the entries will look at today's wild predictions of coming scientific progress with a suitably sceptical eye – we've been getting it wrong for decades.

Incomplete Nature

A tough read but a nonetheless important book on the mind, says **Susan Blackmore**



How Mind Emerged From Matter
Terrence W Deacon
Norton, £19.99
(602pp, hbk)

Anthropologist Terrence W Deacon makes some extraordinary claims in this rich and far-ranging book. Taking on such tough philosophical problems as the nature of function, meaning and value, he argues that we should focus on what's absent, not just what's present.

There's something missing in our science, says Deacon, and that something is itself *something missing* – a no-thing, something absent or not yet actualised that we can't find in the human brain. Deacon suggests that meaning, function, purpose, consciousness, even our sense of self are all 'absential' – just one of many words coined in the book.

Deacon writes well and with extraordinary breadth of scholarship. He explores difficult concepts such as 'emergence' and gives them a new twist by casting them in the light of teleological processes – processes directed towards specific ends. In this way, he travels from the origins of life itself to the most problematic issues such as human consciousness.

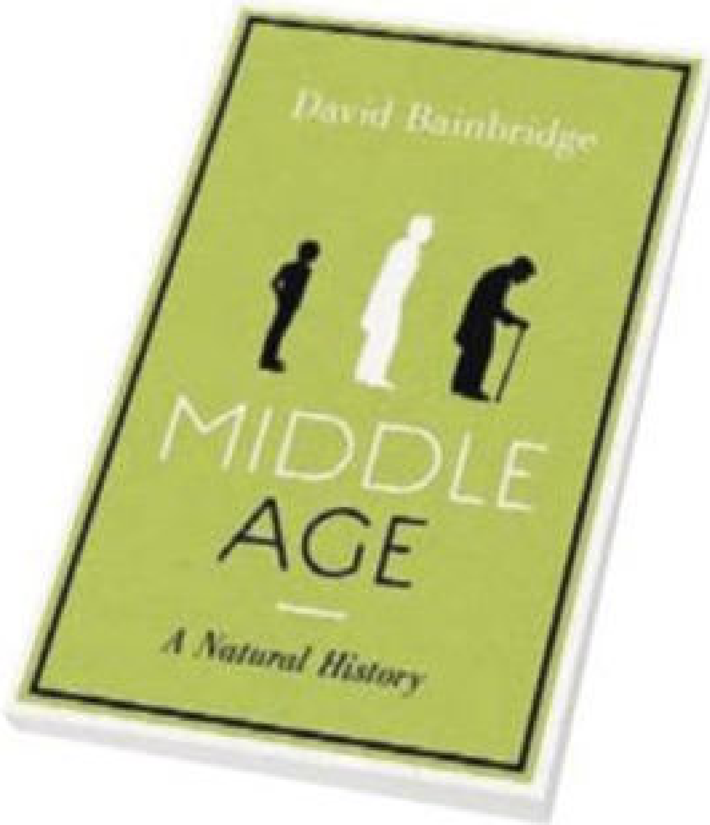
Deacon claims that neurones are sentient agents, as are simple organisms, but that human sentience emerges at a higher level, along with a sense of 'self' and 'other'. He describes a process called 'self-entanglement' that marks the difference between things can be described purely in terms of physics and chemistry – such as a rock or a machine – and things that also entail meaning, function and reference, such as a frog or a human being. Yet there's nothing added when these properties emerge; no mysterious new stuff to find. What we have failed to see is that absent phenomena can be causal. They are absences that matter.

This is undoubtedly an important book but, with around 600 pages of intense philosophical and scientific exploration, it's also tough going. I'll have to read it again before I can decide whether Deacon's theory really does live up to its claims. ●●●●●

***Prof Susan Blackmore is a psychologist and author of* Consciousness: An Introduction**

Neurones in the brain are sentient agents in their own right, argues Deacon

ALAMY



Middle Age
A Natural History
David Bainbridge
Portobello, £14.99
(304pp, pbk)

It's perhaps odd to write a book about middle age. David Bainbridge argues that it has evolved over millions of years to give us special benefits, but from a scientific viewpoint, middle age isn't actually a significant stage of life. All evidence from ancient times shows that, if one escaped juvenile mortality, the most common age of death was around 40. So there was little chance of evolutionary pressures having any influence on middle age.

Nevertheless, this book includes some interesting contrasts. Middle age is a time when the emphasis of our lives can change, not least through changes in our body: muscles become smaller, brains begin to forget, fat accumulates. But it's also a period when many people have their greatest social and economic power, and caring for others can be dominant.

Cross-cultural studies show that the mid-forties are the least happy time in our lives. Sex can present problems, for instance, yet nearly three-quarters of the middle-aged have active sex lives. It's also the time when children leave home and 'empty nest' syndrome kicks in.

According to Bainbridge, middle age requires a complete reappraisal of all aspects of one's life. I found it all a bit confusing, but the book does cover some interesting issues. ●●●○○

***Prof Lewis Wolpert is a biologist and author of* You're Looking Very Well**

How The Hippies Saved Physics

Science, Counterculture And The Quantum Revival

David Kaiser

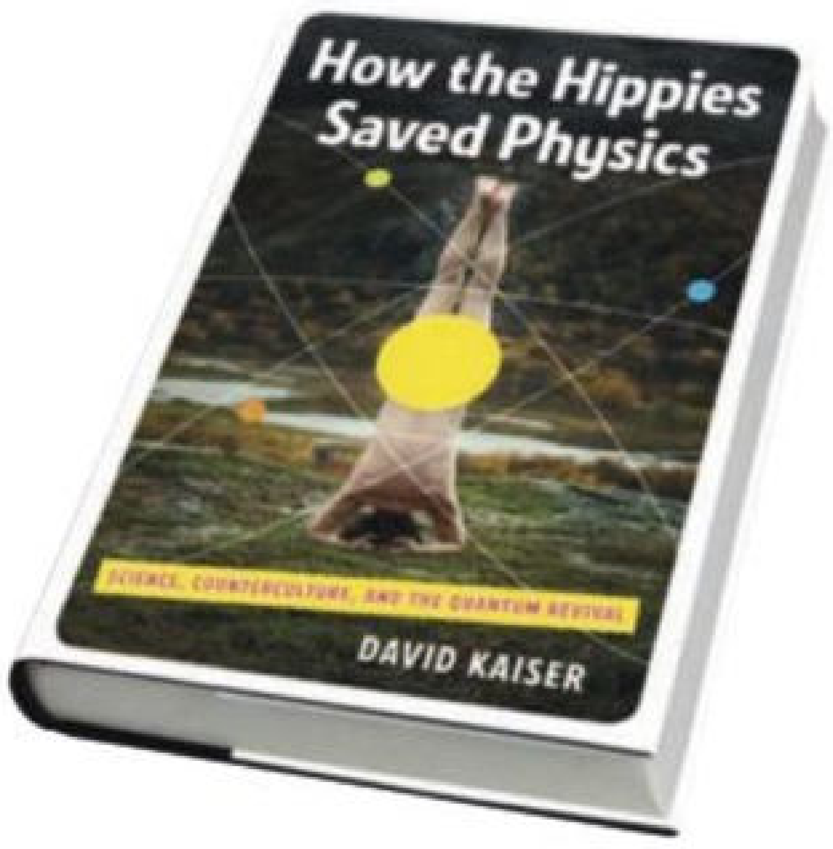
Norton, £17.99

(371pp, hbk)

Of all scientists, physicists have a reputation for being the most hard-nosed and cocksure. How ironic, then, that they gave us the weirdest, flakiest theory ever conceived: quantum mechanics. No-one really knows why it works, yet we all benefit from the fact that it does. Behind all those consumer gadgets, with their microchips, flash memories and OLEDs, lie concepts like wave-particle duality and quantum tunnelling that would only appear worth taking seriously by New Age types. And that *was* pretty much the case in the 1970s, when a group of renegade physicists called the 'Fundamental Fysiks Group' (FFG) began exploring bizarre ideas in quantum theory which mainstream scientists preferred to ignore.

With their penchant for Eastern philosophy and the odd joint, nothing was off-limits – including the idea that telepathy could be a quantum effect. Some of their hobbyhorses, such as quantum entanglement, are mainstream today. But for years, the FFG were pretty much the only ones taking these ideas seriously, and Kaiser highlights the group's key role in keeping some major research themes alive. The title of this book shouldn't be taken too seriously, but the scientific contribution of these hippies with doctorates certainly should. ●●●●○

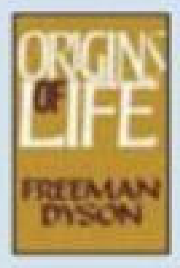
Robert Matthews is visiting reader in science at Aston University



Expert Bookshelf

Life In The Universe

Chosen by **Dimitar Sasselov**



Origins Of Life

Freeman Dyson (1985)

Cambridge, £13.99

Technical at times but written for the most part in a popular style, this book asks: how did life on Earth emerge? Dyson gives a succinct history, then goes into his own views, with an emphasis on the issue of metabolism – the exchange of energy by a chemical system, which then becomes living. Before DNA, Dyson thought of life emerging as 'garbage bags' of molecules capable of chemical reactions.

Our Cosmic Habitat

Martin Rees (2001)

Princeton, £13.99

This book was influential to me because it's written from my perspective, as an astronomer and astrophysicist, but the questions cross disciplines into chemistry, biology and other realms. It's easy to read, yet very deep at the same time. Rees considers how the physical understanding of the Universe connects to life, and how we can learn about that by observing the cosmos.

The Eerie Silence: Are We Alone In The Universe?

Paul Davies (2010)

Penguin, £9.99

The title here, *The Eerie Silence*, comes from the 'Fermi paradox'. If we can develop a technological civilisation able to communicate over long distances with radio waves, how come a Universe that's much older than the Earth and Sun is not teeming with other similar civilisations which could visit or communicate with us? The answer to that paradox, still unknown, is the topic of this wonderfully written book.

Prof Dimitar Sasselov is an astronomer and author of **The Life Of Super-Earths**

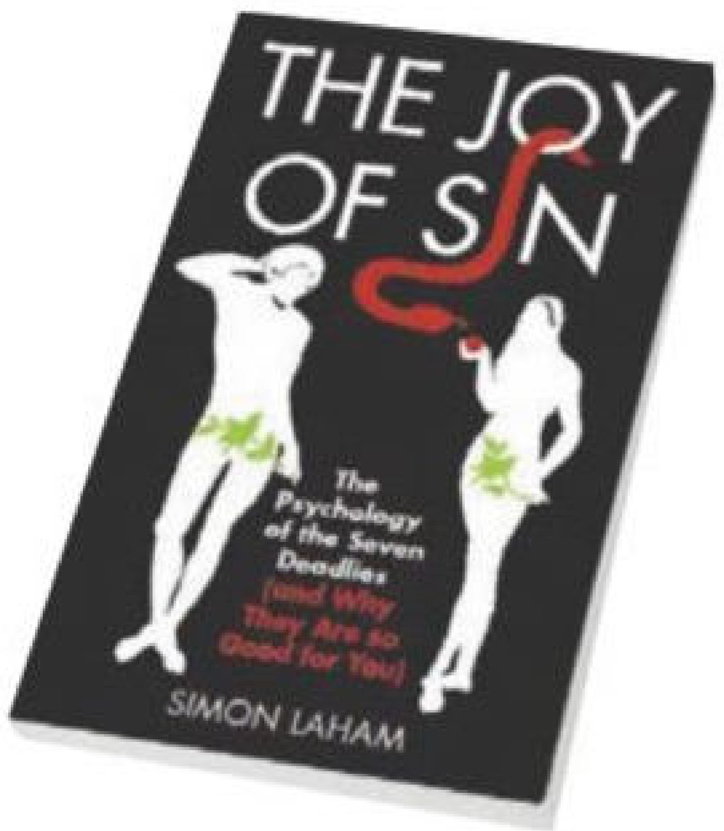
The Joy Of Sin

The Psychology Of The Seven Deadly Sins

Simon Laham

Constable, £8.99

(256pp, pbk)



Social psychologist Simon Laham has put together an amusing take on that old favourite, the seven deadly sins. He argues convincingly and with a great deal of experimental support that, far from being deadly, most 'sins' are actually rather good for us. Lust improves analytical thinking, for example – or as he puts it, "Just before your next exam, watch porn." This book also quotes a *Focus* report from 2010 which listed the world's most sinful countries: go to South Korea for lust, or Australia for envy. ●●●●○

Dr Michael Moseley is a **Focus** ***columnist and BBC broadcaster***

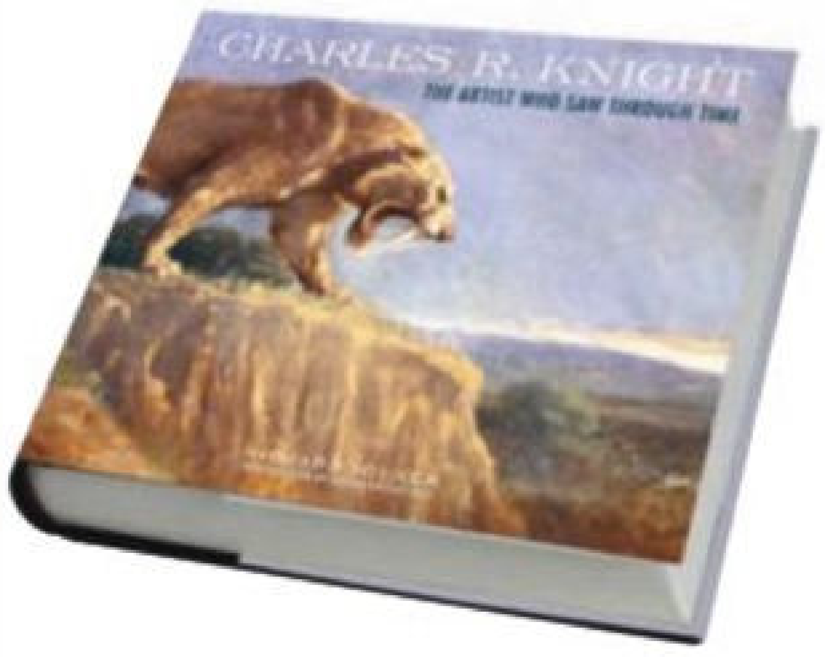
Charles R Knight

The Artist Who Saw Through Time

Richard Milner

Abrams, £24.99

(180pp, hbk)



Charles R Knight (1874-1953) was one of the first artists to paint dinosaurs. His images were seen in magazines and movies, where they exerted a huge influence. This illustrated biography introduces Knight the man – a temperamental artist in classic fashion – and his complex relationships, mainly with Henry F Osborn, director of the American Museum of Natural History. One fact stands out: although Knight made his living through art, his vision was so poor that he was legally blind for most of his life. ●●●○○

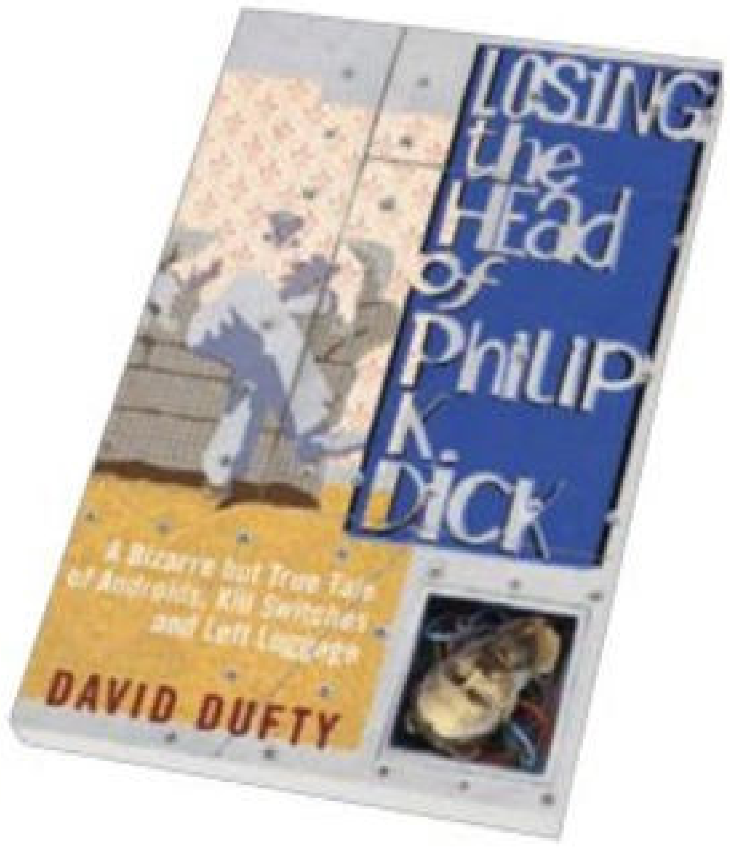
Dr Henry Gee is a senior editor at the journal **Nature**

Losing The Head Of Philip K Dick

David Dufty

Oneworld, £10.99

(272pp, pbk)



On the surface, this is a story about how robot-maker David Hanson managed to leave the head of an android modelled on a science-fiction writer on a plane, never to see it again. But this is only incidental to the true tale, about the exploits of researchers at the University of Memphis, who funded and built one of the most successful humanoid robots to date. The android was infused with the personality of Philip K Dick, whose stories lay behind iconic films like *Blade Runner*, exploring issues of identity, mind and the nature of intelligence. ●●●●○

Bill Thompson is a technology expert and **Focus** ***columnist***

THE TO-DO LIST

The essential guide to the month ahead

8 MARCH

Earthflight

If you missed it on TV, this stunning documentary series brings you unprecedented views of some of the natural world's greatest spectacles. Cameras strapped to microlights, gliders and silent drones capture intimate views of birds' lives in the skies.

DVD: £19.99, Blu-Ray: £25.99, www.bbcshop.com

12-25 MARCH

University Of Cambridge Science Festival

This year's Cambridge Science Festival features over 180 events, running the gamut from evening lectures to hands-on activity days for the kids. Guest director Robin Ince hosts a series of debates and discussions, while other speakers, panellists and presenters include the likes of Alan Moore, Jim Al-Khalili, Helen Keen, Stuart Clark, Anders Sandberg and Clive Oppenheimer.

Various venues and prices, Cambridge, call 01223 766766, www.cam.ac.uk/sciencefestival

21 MARCH

Shocking Bodies

In 1771, the Italian physician Luigi Galvani noticed the legs of the frog he was chopping up starting to twitch. He presumed this 'animal electricity' came from inside the frog, but Volta showed it was because the metal instruments created an electrical circuit. In this talk, historian Dr Iwan Rhys Morus reveals how electricity has been used to investigate the human body. Prepare to be shocked!

Wellcome Building Conference Centre, London, 6-7pm, free, www.bshm.org.uk/poynter.htm

18/30 MARCH

EDITOR'S CHOICE

Paul Rose

You may recognise Paul Rose from BBC TV series such as *Oceans*. The presenter and explorer has led polar expeditions and trained emergency response dive teams. He is Vice President of the Royal Geographical Society and was Base Commander of the Rothera Research Station in Antarctica.

Having worked in the Antarctic for 10 years, receiving the Queen's Polar Medal for his efforts, Rose really knows what it's like to live and work in the frozen wilderness. On 18 March, he'll be discussing life on the icy continent in two daytime talks at the Natural History Museum.

Then on 30 March, he teams up with Dr Iain Grant, an expert in polar medicine, and Tori James, the youngest woman to climb Everest, to discuss the limits of human endeavour. Why do some people risk their lives to explore the planet? When facing death, what happens to you psychologically and physically – and do we all react differently? Find out from the people who know from experience.

Natural History Museum, London
Meet An Antarctic Base Commander: 18 March, 12.30pm and 2.30pm, free, www.nhm.ac.uk/nature-live
Exploring The Human Limit: 30 March, 7-9pm, £10 (£9 for members), www.nhm.ac.uk/after-hours

IAN KELLETT, NATURAL HISTORY MUSEUM, BBC X2, STEVE DOWNER/ARDEA, NATALIE STERNBERG, ALAMY, UNIVERSITY OF CAMBRIDGE

21 MARCH

William Smith And Making Geological Maps

Love poring over maps? At this talk, learn about the man who published the first geological map of Britain in 1815. Incredibly, some of Smith's methods are still used by geologists today. There'll also be a chance to see his stunning hand-painted map.

Natural History Museum, London, 2.30pm, free, www.nhm.ac.uk/nature-live

25 MARCH

The Thing Is… Brain Wars

Join author Ken Hollings and Quentin Cooper from Radio 4's *Material World* as they examine how perceptions and treatment of mental illness have changed over the past century.

Wellcome Collection, London, 3-4pm, free, www.wellcomecollection.org

31 MARCH

The Name Game

Vampyroteuthis infernalis means 'the vampire squid from hell', while *Ba humbugi* is a snail from the island of Mba. Ever wondered how newly discovered species are named? Find out at this talk, and join in the game to decide which names a panel of scientists have made up and which are real.

Natural History Museum, London, 12.30pm and 2.30pm, free, www.nhm.ac.uk

LAST CHANCE TO SEE

UNTIL 31 MARCH

Giants Of The Infinitesimal

Nanoscience could be the answer to many of our planet's problems, from clean energy solutions to nanomedicines. The large scale models in this interactive exhibition reveal the hidden forces at work in the nanoworld: you can wrestle with magnets and currents, make a nanowire and watch graphene vibrate, all while learning how these structures form and how nanomachines work.

MOSI, Manchester, 10am-5pm, free, j.mp/NanoGiants

5 APRIL

Edible

Learn about science while filling your belly. From recipes for glowing sushi to 'vegetarian' fish soup made from tomatoes with fish genes, explore how biotechnology is creating new foods. Taste smog, crawl through a giant inflatable stomach, and discover the future of food. At the daily Feeding Time and the fortnightly Dining Experience, you'll be able to sample some unique dishes.

Science Gallery, Dublin, free (Feeding Time €2, Dining Experiences €40), www.sciencegallery.com

UNTIL 13 MAY

Fénix 2, Icon Of The Chilean Mine Rescue

In late 2010, 33 Chilean miners were trapped 700m underground for a record 69 days – and survived. The world watched on TV as 'Los 33' were finally hauled safely to the surface, bringing a successful conclusion to a rescue attempt that had cost $20 million. Now, here's your chance to see the 3.9m-tall, 460kg capsule in which they were rescued for yourself.

The Science Museum, London, 10am-6pm, free, www.sciencemuseum.org.uk

TV & RADIO

The month's top science programmes

Bang Goes The Theory

BBC One,
Starts 12 March
Mondays, 7.30pm

Jem, Liz, Dallas and Doctor Yan return with the series that likes to get down and dirty with the latest science and the most entertaining technology. As usual they're being coy about exactly what will be revealed in series six, but we can give you a few hints.

The boys will be checking out alternative fuels by racing their mean machines along Broadstairs beach in the rain. That's mean in the sense of 'stingy', as the most frugal vehicle will be the victor. The first casualty of beach racing is, perhaps unsurprisingly, the riders' dignity.

Liz gets some WW2 history in with Colossus, the computer that solved the German Enigma codes. As the name suggests, it's no tablet – in fact, it fills a good-sized room. Jem takes to the skies, while Dallas gets to do something very smelly on a farm. And whatever Doctor Yan has up his sleeve may or may not involve balls of steel.

If we told you any more we'd have to kill you. Or get you involved in one of Jem's experiments…

The *Bang Goes The Theory* team return to a TV screen near you this month

How Life Works

BBC Two,
TBC

Wildlife expert Chris Packham travels the world to see how the complex interactions of competing plants and animals create the varied habitats that cover the globe. His aim is to show that the termite needs the rhinoceros, the shark can't do without the tiger, and the lynx relies on the caterpillar. To us, the insects of the jungle are an annoyance, but it's their infestation that makes the jungles of Borneo possible. In Kenya the grasslands are not destroyed by grazing rhinos and giraffes, but revived and nourished. In the waters of South America and the Indian Ocean, things get even more complicated, as plants and animals struggle with a shortage of oxygen and an ever-changing environment.

When Weather Changed History

Discovery Science,
starts 22 March, 8pm

Living in a temperate climate, it's easy to forget how much the weather can still devastate human lives. This series looks at some dramatic examples, including a 'super outbreak' of 148 tornadoes that ripped across North America. Other examples are less obvious. The loss of Delta Flight 191, killing 135 people, was ascribed to microburst-induced wind shear. This rare phenomenon was utterly unforeseen at the time; now, thanks to predictive wind shear radar, such tragedies can be avoided. Finally, Space Shuttle Challenger blew up on launch following very cold weather that allowed a fatal leak of fuel. That led to a rethink of the entire system to make it truly weatherproof.

BBC X2, PRESS ASSOCIATION, GETTY, NASA X2

Radio

The Human Race: The Life Of An Athlete From Cradle To Grave

BBC World Service, starts 7 March

How does a talented youngster become an Olympic-class athlete? Four programmes start with childhood training and the role of natural ability, from China to the runners of Kenya. Then we hear about how nutrition, specialised training and psychology hone physical abilities to outstanding levels. From altitude training to drugs, what extreme techniques are healthy, wise or even legal? Finally, what happens to an athlete's mind and body when the training stops? American scientists study retired athletes to find out.

Scott's Legacy

BBC Radio 4, starts 13 March, 11am

At the time of his expedition to the South Pole, Captain Scott was hailed as a hero, despite the tragic end of his endeavour. More recently, he has been criticised for sacrificing the lives of his men and himself for a race that they lost to the Norwegian Amundsen. But in this two-parter, Dr Kevin Fong argues that exploring the unknown is always worthwhile.

It's My Story: The Long Walk

BBC Radio 4, 26 March, 8pm

If you or I see unattended luggage, we're urged to move away and report it. But what if your job was precisely to walk towards it, knowing it could blow up at any time?

Peter Gurney, former head of the Metropolitan Police Explosives Squad, reflects on the longest walk – the one a bomb disposal officer makes alone to a suspect package. He's spent a lifetime in the business, and now he shares his memories and thoughts.

Seconds From Disaster

Nat Geo, starts 11 March, 9pm

Historic disasters are revisited as the investigative series returns. First up: Fukushima, a casualty of Japan's devastating earthquake and tidal wave. What should have been done to prevent nuclear contamination adding to the post-tsunami chaos? Then we go further back in time, looking at a 1963 landslide that caused a lethal Italian flood, and at the sinking of the 'unsinkable' Bismarck in 1941.

Untamed China

Animal Planet, starts 11 March, 8pm

There's more to China than bamboo and pandas. Its landscapes include mountains, deserts and jungles, and Nigel Marven travels them in search of little-known wildlife. This six-part series takes him from rolling grasslands to the ancient city of Dali. On the way he faces deadly reptiles, ethereal butterflies and the rare Yunnan snub-nosed monkey.

Rebuilding Japan

Discovery, starts 12 March, 8pm

Futoshi Toba lost his wife in last year's earthquake and tsunami, one of 20,000 casualties. But as the new mayor of Rikuzen Takata, he has to concentrate on rebuilding his city. One year after the disaster, this series follows Toba and the experts helping him lead his community back to normality. He seeks out technological advances that will help the city return to life without losing its spirit.

Lost Civilisation

Nat Geo, 13 March, 9pm

Stonehenge, around 5,000 years old, was an impressive achievement for our Stone Age predecessors. But almost 12,000 years ago, before the wheel, written language, or even agriculture, people built a series of carved stone circles in Turkey. Older than the Egyptian pyramids, they required organised work by humans who had no pottery or metalworking. How did they do it? And what can it tell us about the birth of civilisation?

Bravo November

Discovery, starts 26 March, 9pm

Mike Brewer looks at the history of the Chinook helicopter through one special machine. Now in active service in Afghanistan, it played a key role in the Falklands War 30 years ago. After riding along with a medical emergency team to evacuate a casualty, he meets the pilot and mechanic who kept the machine flying in the South Atlantic, and finds that this Chinook engenders strong emotions in the men who fly and maintain it.

Drain The Great Lakes

Nat Geo, April, exact dates TBC

America's Great Lakes contain 20 per cent of the planet's fresh water – enough to cover the USA to a depth of 2.7m. This film uses new research and CGI to go beneath the surface and find some surprising features: a submerged waterfall that's evidence of water levels 7,000 years ago, traces left by early humans, and a crater that could be the result of a falling meteorite. The deeper we go, the further back in time we can see.

BRAINTRAINING

Pit your wits against these brainteasers by **David J Bodycombe**, question-setter for BBC Four's *Only Connect*

Prize Puzzle

Complete this sentence using two seven-letter words. The two words are identical except for their last letters, which are adjacent in the normal alphabet.

The_____ criminal waited in his_____.

The first three correct entries drawn from the *Focus* hat will each win a Mini Maglite torch. Send your entry, marked 'Prize Puzzle 240', to the address on p117 by 5 April. We regret that we cannot accept email entries.

See ***sciencefocus.com/winners*** for previous winners and solutions

QUESTION 1

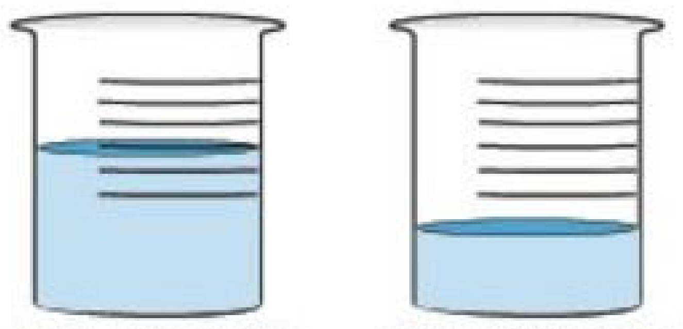
What nine-letter word can be formed when you mix together WIND and FROST?

QUESTION 2

What is the missing term in this sequence: India, Victor, ____ , Lima, Charlie, Delta, Mike?

QUESTION 3

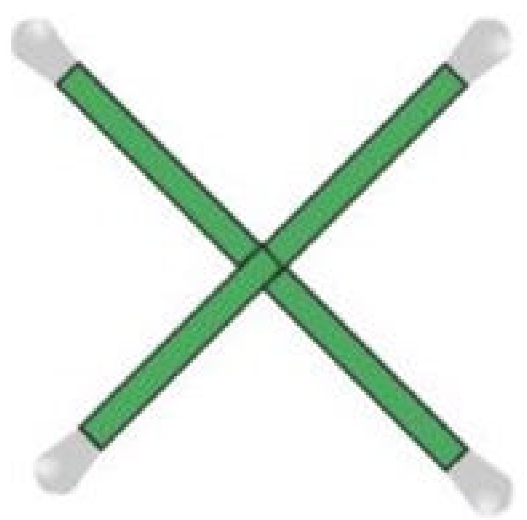
If the water in these two jugs was mixed, what would the resulting temperature be? You may assume no heat loss.



500ml @ 15°C 250ml @ 60°C

QUESTION 4

Move one match to form a square



QUESTION 5

B C D E G P T V

Anne thinks that these eight letters have something in common. Barbara, however, thinks there is one letter missing from the group. What can you deduce about Anne and Barbara?

QUESTION 6

Which eight squares should be shaded in, to make this a valid crossword with half-turn symmetry?

	1	2	3	4	5	6
A	P	E	R	M	I	T
B	E	G	O	A	R	E
C	A	G	E	T	O	E
D	L	Y	M	A	N	Y
E	E	B	O	X	I	E
F	D	E	F	E	C	T

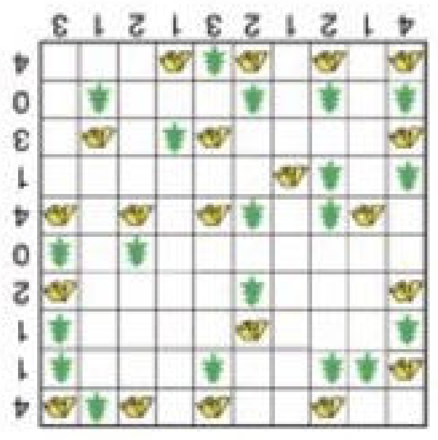
QUESTION 7

Steve went to the greyhound races with £64. On each of the six races, he bet half the money that he had on the even money dog. Half the dogs he backed won. Ignoring betting duty, how much cash did he end up with?

QUESTION 8

Place tents in the empty squares so that the number of tents in each row and column matches the numbers shown. Every tent must be immediately next to a tree (horizontally or vertically). One tent per square only. Tents are never adjacent to each other – not even diagonally.

								🌲		4
	🌲	🌲			🌲				🌲	1
🌲									🌲	1
				🌲						2
							🌲		🌲	0
		🌲		🌲						4
🌲		🌲								1
						🌲				3
🌲		🌲		🌲				🌲		0
					🌲					4
4	1	2	1	2	3	1	2	1	3	



Solutions

Q1) SNOWDRIFT. Q2) X-ray. They're the Roman numerals I, V, X, L, C, D and M, converted into the NATO alphabet. Q3) 30°C. Use a weighted average as follows: ((500 x 15) + (250 x 60)) / 750 = 30. Q4) Move the match at the bottom left slightly outwards. A very small square is then formed in the middle. Q5) Barbara is American. The eight letters rhyme: Anne pronounces Z as 'Zed' but Barbara pronounces it as 'Zee', which rhymes with the others. Q6) B2, B6, C4, C6, D1, D3, E1, E5. Q7) £27. It doesn't matter which races he won and lost – the result's always the same. Q8) See illustration.

Quick Quiz

Test your knowledge of supercomputers

QUESTION 1

The first 'supercomputer' was 1964's CDC 6600, built by who?

a) Seymour Cray
b) Steve Wozniak
c) Gordon Moore

QUESTION 2

Which of the following is NOT a real supercomputer?

a) GRAPE
b) CaROL-V
c) Deep Crack

QUESTION 3

The Chinese supercomputer Tianhe-1 takes its name from the Mandarin for what?

a) Milky Way
b) Lightning bolt
c) Roadrunner

QUESTION 4

Supercomputers' speed is measured in Petaflops. That's how many floating point operations per second?

a) One billion (1x 10^9)
b) One trillion (1x 10^{12})
c) One quadrillion (1x 10^{15})

QUESTION 5

The first computer to reach Petaflop speeds was built by IBM in 2008. Can you name it?

a) Roadrunner
b) Sequoia
c) Blue Waters

QUESTION 6

Which operating system is used by over 90 per cent of current supercomputers?

a) Linux
b) Mac OS X
c) Windows 97

QUESTION 7

What is the top speed of Japan's K Computer, the most powerful in the world?

a) 3.14 Petaflops
b) 8.16 Petaflops
c) 10.51 Petaflops

YOU ARE:

0-2 A bit slow
3-5 Mega brainy
6-7 Peta than the rest

Answers: 1a, 2b, 3a, 4c, 5a, 6a, 7c

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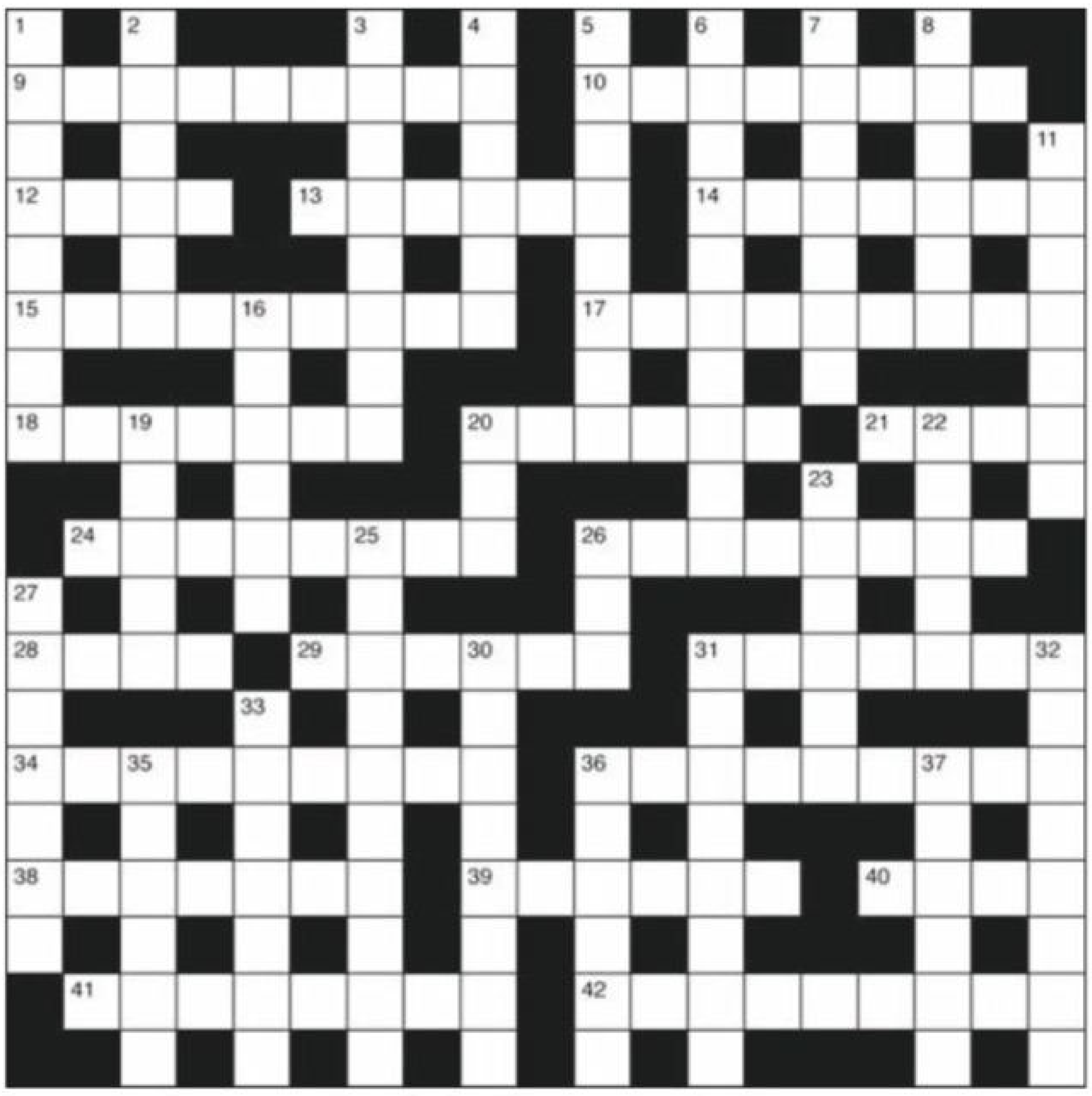
Focus crossword Nº 139



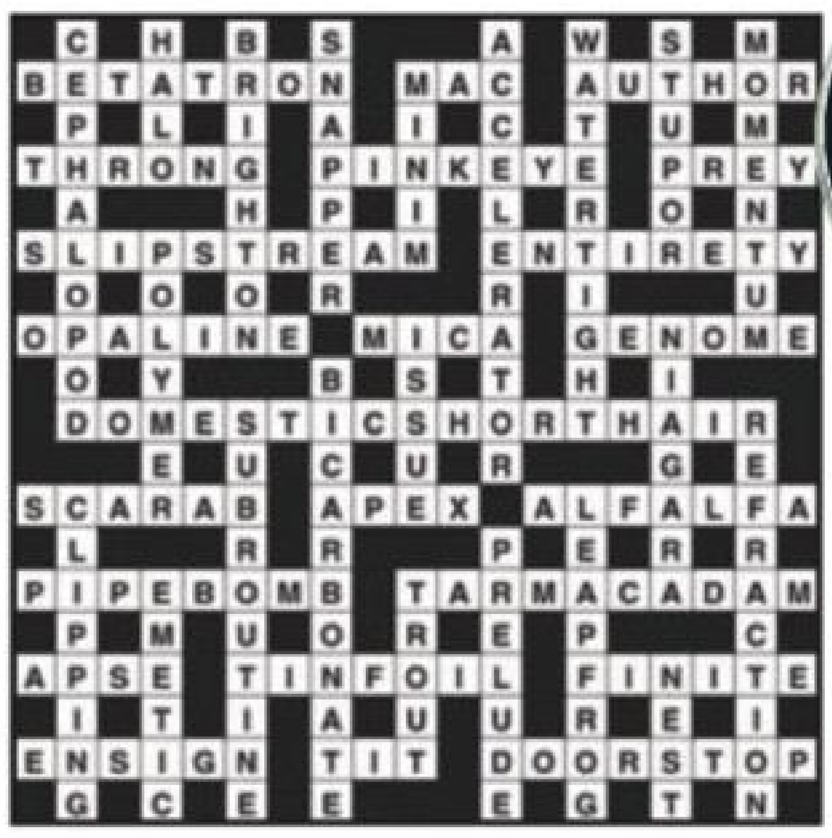
Across

9 During examination at home, point to part of gut (9)
10 Diamonds sure to be caught in cold climate (8)
12 Insensitive to new university doctor (4)
13 I'm upset by anger at trick of the light (6)
14 Only one student has healthy source of fuel (3,4)
15 Japanese comics seen out of their element (9)
17 I'm that ace, working without a common thread (9)
18 American uncle first to break the core (7)
20 Graduate has glue made of fish (6)
21 Greet an oscillation (4)
24 Find problem with unusual part of spectrum (8)
26 Actors join press firm (4-4)
28 A study of port (4)
29 Missing school group has coins (6)
31 A lyric about carbon polymer (7)
34 Stomach failure of bad dive (5,4)
36 Slow communication from a mollusc (5,4)
38 Shape of flower made of brass (7)
39 Bishop finds two under a dog (6)
40 Turn up with mother's cat (4)
41 Glass boat (8)
42 Rascal gives energy to routine resistance (9)

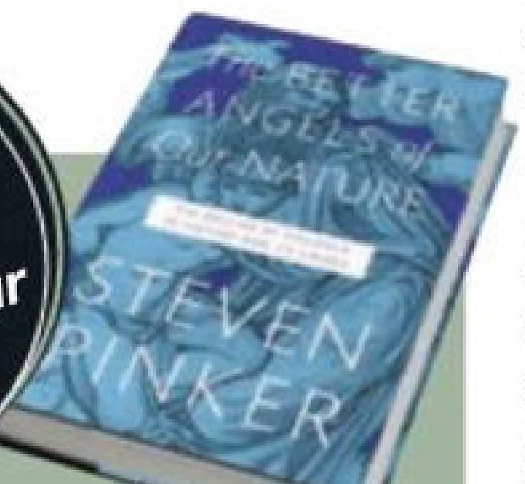
Down

1 No manic return with new spice (8)
2 Flower part sent off around morning (6)
3 They share a compass (8)
4 Soldiers take a long time finding household (6)
5 Drop twisted wire in as a security measure (8)
6 Laugh as soup goes spinning round the gullet (10)
7 Only union left in search for some charge (7)
8 Creature found in group (6)
11 Gal cooked rice, forming a cold lump (7)
16 Deity is the last word to an artist (4-2)
19 Ocean wrong for such a vessel (5)
20 Shoot a friend (3)
22 A charge to see a coral island (5)
23 Threadlike structure to lie right on one lake (6)
25 Wave at military vehicle found in physics lab (6,4)
26 Copper gets point of signal (3)
27 Second sailor reaches tub and has a rest (7)
30 Upset by a carp and a rodent (8)
31 Hang a ply construction in stereoscopic view (8)
32 Mixed composition, nitrogen and protein (8)
33 Indication to stop my plan to get married (7)
35 Dispatch a motorboat (6)
36 Motionless form of electricity (6)
37 Graduates from Milan break up and turn in (6)

Solution to Nº 136



Win The Better Angels Of Our Nature



The first three correct solutions drawn from the *Focus* hat will each win a copy of *The Better Angels Of Our Nature* by Stephen Pinker. Send your entry marked 'Crossword 139' to the address below by 5 April.

Congratulations to DE Heaney (Blackpool), Chris McCullough (Co. Down), Mr TG Price (Bridgend), Mr P Lusby (Doncaster) and Paul Judge (Elstead), who correctly completed Crossword No 136 in the January issue and each win a copy of *Frozen Planet* on DVD.

YOUR DETAILS

NAME:

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POSTCODE: **TEL:**

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Send your entry to *Focus* at the address below. Entrants must supply to Immediate Media Company Ltd their full name, postal address and daytime telephone number. Immediate Media Company, publisher of *Focus*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' if you prefer not to receive such information by post or phone. Please write your email address on your entry if you prefer to receive such information by email.

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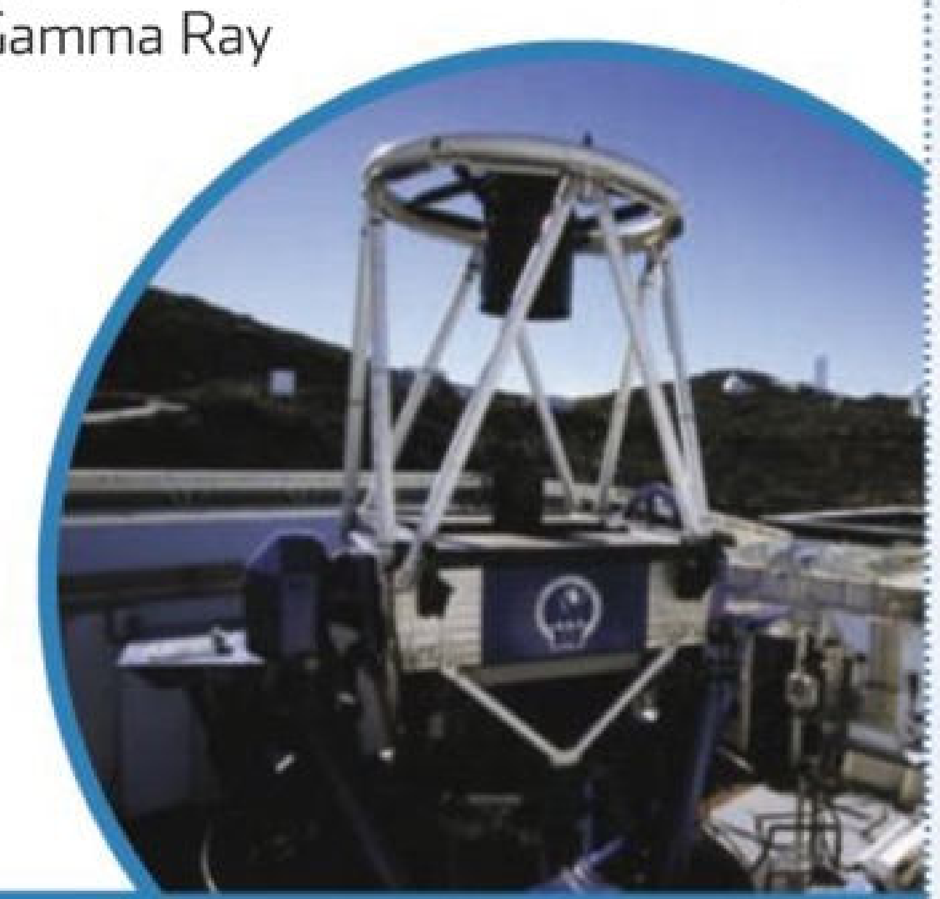

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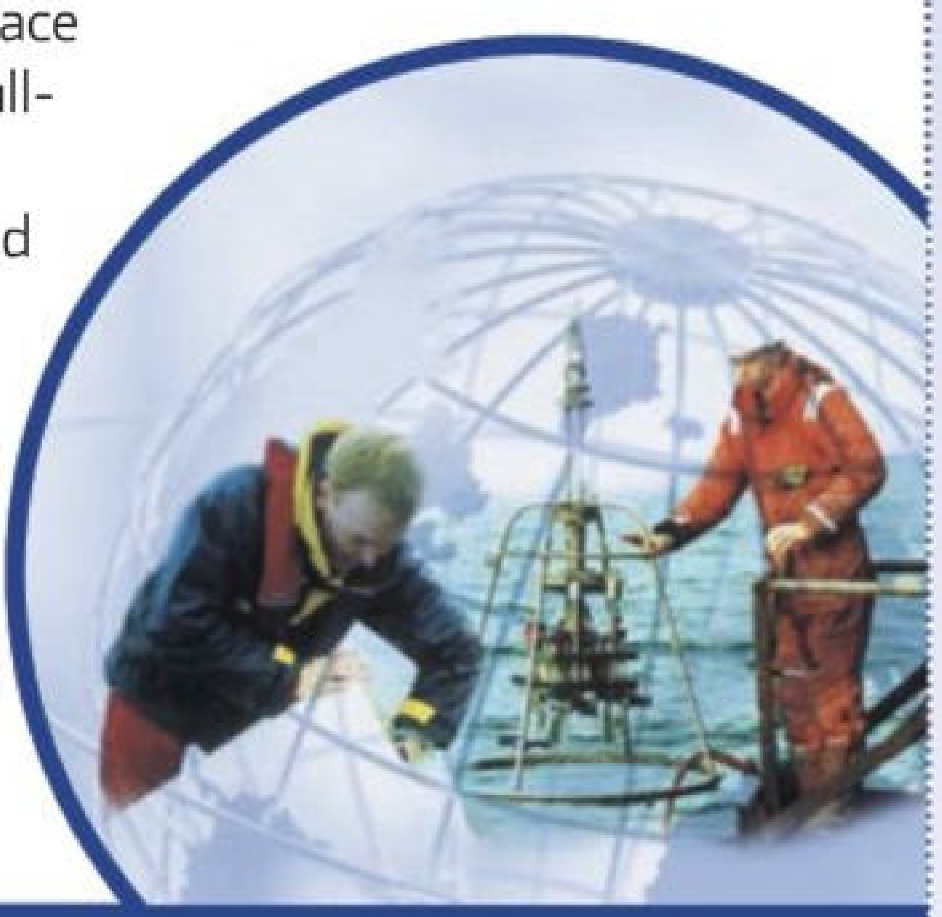

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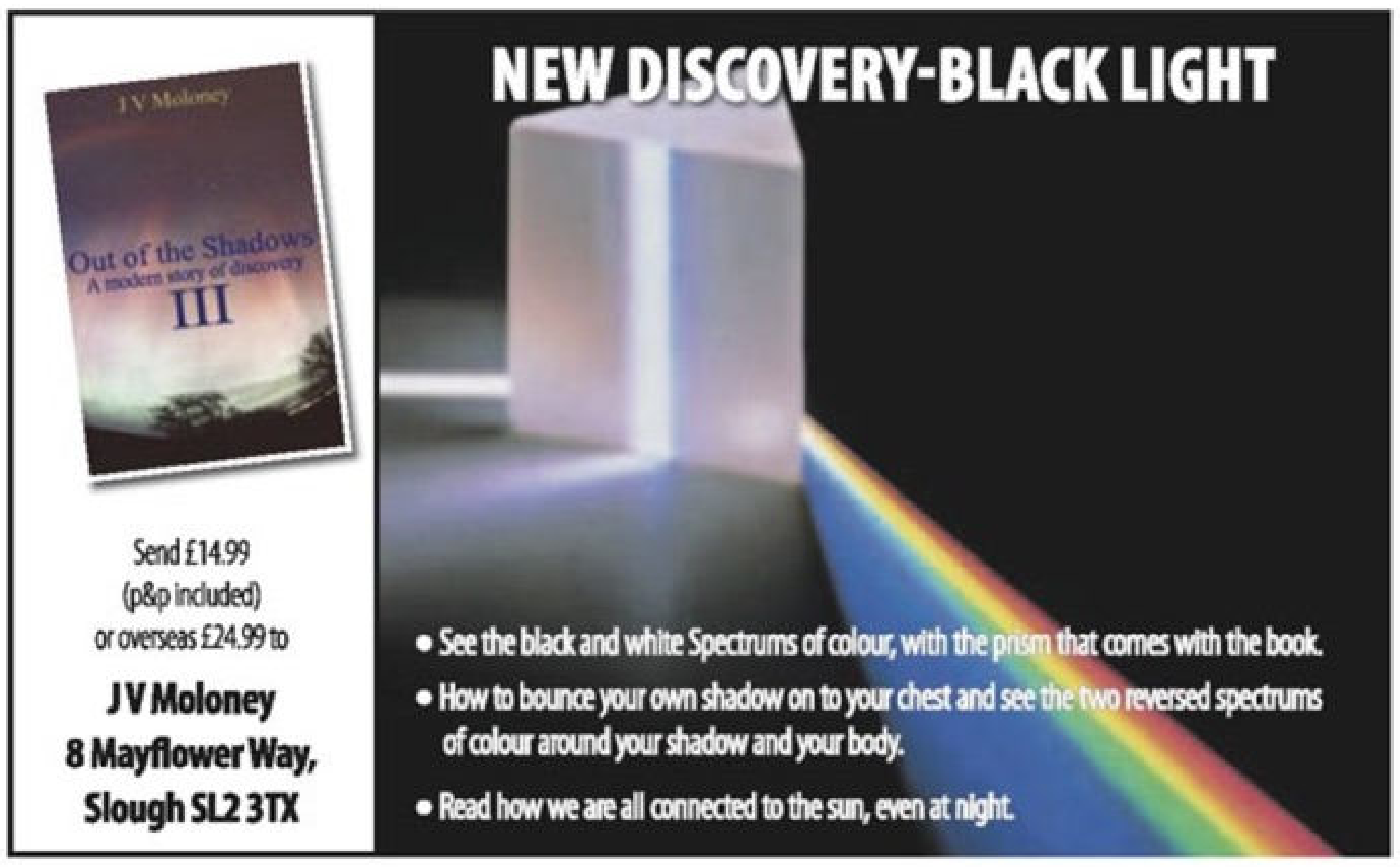
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page 90

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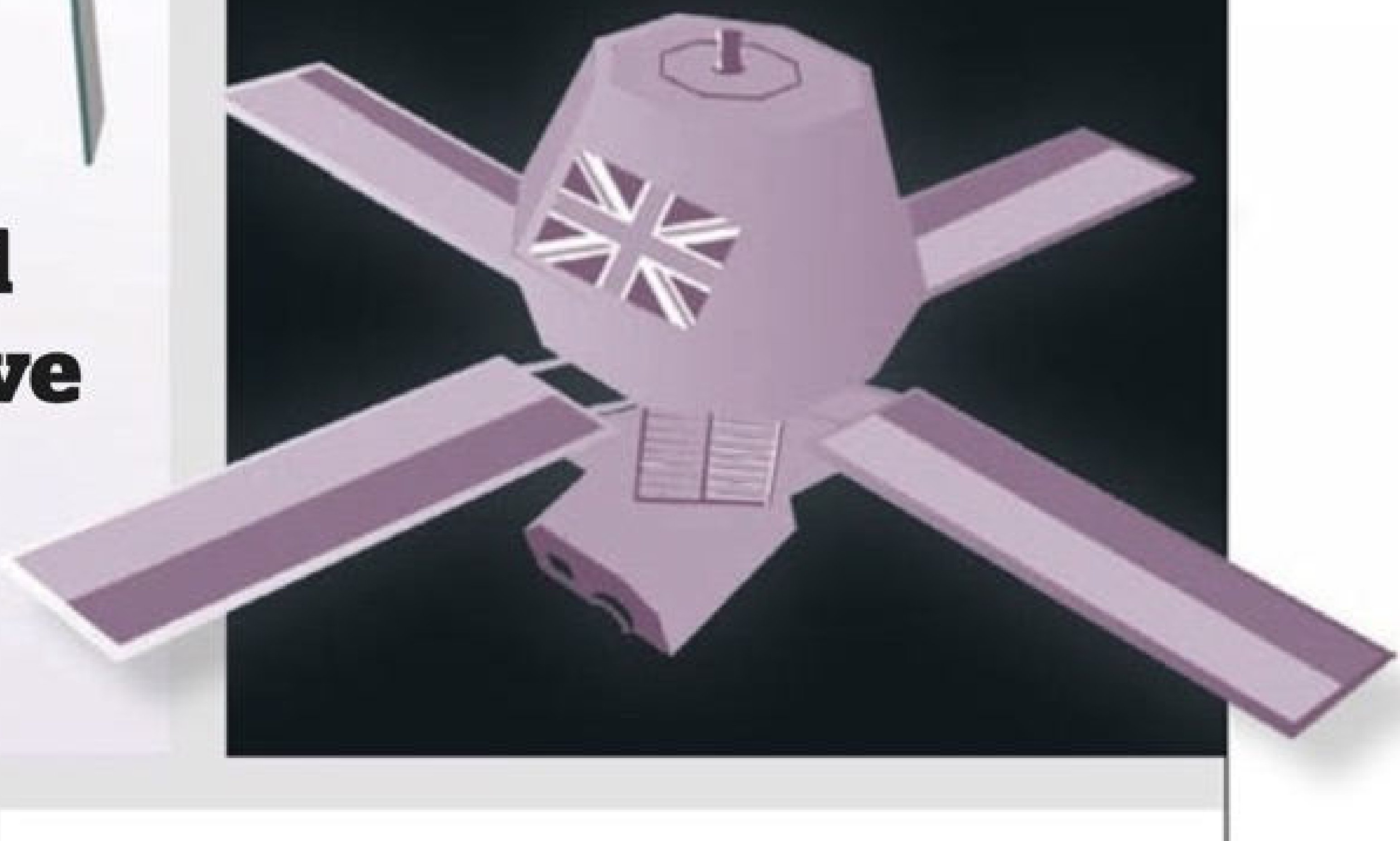
40 per cent of the world's communications satellites are built in the UK
page 48



Neutrinos come in three 'flavours': electron, muon and tau page 77

The Philippine tarsier, a tiny primate, communicates ultrasonically
page 22

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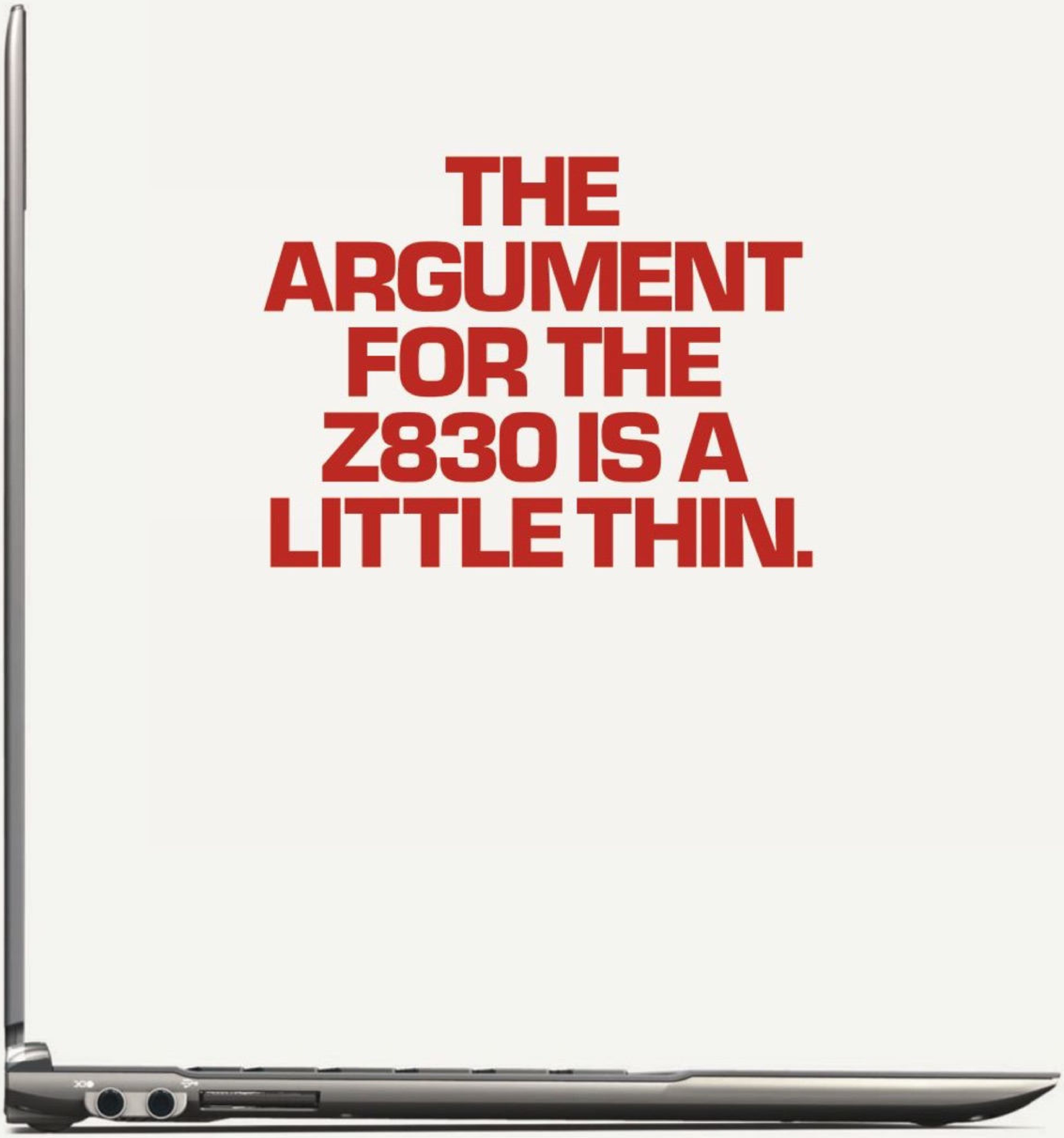

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